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THESIS

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Submitted in partial fulfillment of
the requirements for the degree of

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THESIS

ECONOMIC AND TECHNICAL ASPECTS OF PLASTICS IN ARCHITECTURE AND COMMERCIAL DISPLAY AND MERCHANDISING

by

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(B.I.E. Northeastern University 1929)

submitted in partial fulfillment of
the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

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IN
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SECTION I - INTRODUCTION

This thesis is for the purpose of noting the general extent of the present application of plastics for architectural, merchandising display and commercial purposes, to indicate the apparent future trends in plastic applications in these fields and to give a brief summary of the plastics industry, its methods and products.

Today "plastics" is a magic word. When a new commercial product is noticed having different material characteristics from wood, metal, glass or common fabrics, the observer makes a marveling but vague remark as to "plastics" to explain the material. The availability of more and more plastics products, however, tends to make the field, as a whole, commonplace until some new application is developed, upon which, general interest is revived.

The large and increasing field of novel plastic materials developed from the chemical reactions of various elements is fairly new--at least new applications are being made constantly--and when these are developed in the form of brightly colored or transparent consumer products the entire field is emphasized in the public mind. Accounts of new materials from farm products particularly appeal to the public as wonders of science, but many times these products are used only as fillers to conserve the more expensive chemical elements which possess the important technical characteristics of the raw plastic material, or the brightly finished home-use product which fascinates the consumer by its lightness and translucency. Many industrial applications are less appreciated and the prosaic appearance and more technical purposes of such plastic articles do not impress the average visitor who may pass through a factory on an

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inspection trip, yet these industrial plastics are fully as important as are the items on sale in department stores.

New as the field may appear, some of today's materials are, in fact, quite old and some of the common products from "away back" are as much plastics as the new ones. Every one knows celluloid but until recently it was only another commodity. Today it is still a commodity but may now be recognized as the living grandfather of the present highly developed and highly technical but popular industry. This technical product, Nitrocellulose, was discovered between 1865 and 1870 and by 1880 the annual value of miscellaneous celluloid products made in eight establishments in America was $1,261,540.[(1)]

The principles of synthetic resins, the basis of many plastics, were known years before the general catchall name "Bakelite" became popular some years after Dr. Leo Baekeland's discovery of a fundamental formula in 1909. Presently a chronological list of dates will be used to introduce common plastic materials by their family names, after which, in later sections, brief accounts will be given of chemical composition and uses as well as popular material names coined by the chemical industry.[(2)] At this point, however, it is necessary to define the general term "Plastics" as well as possible, for an adequate definition is difficult.

A. Plastics Definitions

It must be appreciated at the outset that the field of plastics covers a group of products chemically developed and resulting in general from the final setting of materials which were in a liquid or

(1) Modern Plastics, Vol. 18, No. 9, May 1941, pp. 50 and 98
(2) Refer Table No. I, p. 6 of this thesis

moderately pliable state at some point in the manufacturing process. Some of these products when completed form new materials which are actually rigid under all subsequent conditions, but many others may again be made "plastic" as the word is commonly understood, by the application of heat, even after the article is finished. When the material cools, however, it becomes once more rigid or flexible, It is evident, therefore, that our plastic does not mean a finished product which can be shaped at will by the ultimate user. It is more an industrial name indicating products made from a plastic state, and applied to a group which may or may not contain metallic elements.

A technical but tentative definition offered by A. F. Randolph in 1938 is as follows:

> "A plastic is a material which contains as its essential ingredient an organic binder and which at some stage in its manufacture or in the fabrication of articles from it, is capable of being shaped by flow while in a plastic or liquid condition, and thereafter is capable of being brought to a more or less rigid condition." (1)

This definition would include soft rubber and exclude so-called inorganic materials such as glass, Portland cement and cold moulded products of certain types. Some of the cold moulded materials are frequently included as plastics, however, and some attention will be given to them in the sections describing plastic materials.

The foregoing definition in its mechanical aspects is substantiated by another brief definition by Carleton Ellis:

> "The term plastic is applied to anything which possesses plasticity, that is, anything which can be deformed under mechanical stress without losing its cohesion, and is able to keep the new form given to it." (2)

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(1) Randolph, A. F., The Properties of an Ideal Plastic, Am. Soc. Test. Mat., (Philadelphia, 1938), p. 1

(2) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth England, 1941) p. 10

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In the case of plastics materials the foregoing definition applies only to the hot stages during manufacture at which time the new and permanent form is acquired. Another distinction between plastic and plastics is stated as follows: Plastics refers to a class of materials or products made from these materials, whereas plastic refers to a property of a given material which may not necessarily be one of the plastics. (1)

B. Early Forms of Plastics

Pioneer plastics occurred as extracted resins in early Egyptian and Roman history, examples of which are the seals used on ancient documents. More recently phonograph records, an application of a shellac plastic, has carried on in the interim before present public acclaim. Bitumen plastics, later to be mentioned under "Cold Molded" were also forerunners of the present industry and were used for bottle stoppers.

1. Celluloid

Celluloid was discovered in 1865 by an Englishman, Alexander Parkes, who was trying to create a synthetic horny material to substitute for natural animal horn. (2) The new product resulted from a mixture of nitrocellulose, camphor and alcohol and in England was called Parkesite and later Xylonite. This material in America dates from about 1869 to 1875. Previously in 1846 Schonbein had discovered the nitrocellulose. (3)

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(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 13
(2) Simonds, H. R., Industrial Plastics, Pitman, (New York 1941) p. 9
(3) Ibid, p. 8

2. Casein and Cellulose Acetate

Casein is referred to in connection with pigments in 18th Dynasty Egypt, but in 1897 Krische and Spiteller in Germany discovered today's Formaldehyde-casein reaction. (1)

Also in 1865, cellulose-acetate was discovered by Schutzenburger while trying to correct the inflammable nature of celluloid, but it was not commonly used until the first World War when its solution was used for aircraft dope. Its later development in England paralleled the acetate rayon industry as both products required this base material. (2)

3. The Acrylics

The acrylics, vinyls and styrols are a related group. Early discoveries were not immediately used. Styrene dates from 1831 and acrylic acid from 1843. Styrene was developed by Berthelot, however, in 1867 and acrylic by Bauer in 1927. Practical vinyl resins date from about 1920.

4. Bakelite

Although these plastic ingredients for the thermoplastic group of materials were interesting, the plastics industry as such actually began with practical thermosetting materials such as Bakelite, first discovered by Bayer in 1872 and adapted by Baekeland in 1909. Phenolic resins, of which Bakelite is a member, were used as shellac substitutes in varnish prior to 1916 but in this year the first phenolic powder for molding was produced. Urea, as a thermosetting plastic base, became commercially practical in 1925 and resulted from efforts to find a

(1) Simonds, H. R., Industrial Plastics, Pitman (New York 1941) p. 10
(2) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 14

colorable base for Bakelite products which were usually black or brown. Urea, as an organic substance synthesized from inorganic substances,was known one hundred years ago but had no field until recently (1924). (1)

Other plastic discoverers are acknowledged but the preceding group are generally recognized among the earliest originators of the early materials. Many new combinations are being developed constantly and since some of these come from modern corporations, the identity of individuals tends to be lost to the public. Thus in the following chronological list of modern dates many additional products appear:

TABLE NO. I

CHRONOLOGICAL ORDER OF PLASTICS DISCOVERIES

Date	Material	Date	Material
1870	Nitrocellulose	1933	Vinyl Benzine
1875	Celluloid	1933	Benzyl Cellulose
1904	Casein	1935	Vinyl Chloride Polymers
1909	Phenol-Formaldehyde	1936	Ethyl Cellulose
1911	Cellulose-Acetate	1938	Polystyrenes
1919	Vinyl Acetate Polymers	1939	Cellulose Acetate-Butyrate
1924	Urea-Formaldehyde	1940	Mellamine
1926	Alkyd	1941	Polythene
1931	Acrylic Esters	1941	Vinylidene
1932	Methacrylic Esters		

Source: Simonds, H. R., Industrial Plastics, Pitman (N.Y. 1941) p. 4

(The above list of dates does not include the dates on which various adaptations of the same materials to other forms occurred and there is some slight difference in the actual discovery dates depending on the authority. Certain borderline materials previously mentioned are not included in this list but will be mentioned later.) (2)

(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 16

(2) See pages 3 and 21 of this thesis

C. Economics of the Plastics Industry

1. General Position of the Industry

With this brief summary of the field of commercial plastics materials as a background, some attention should now be given to the size of the industry. The figures below indicate the enormous growth of plastics and show the broad field of future opportunities for plastics in supplying a multitude of purposes both in consumer and producer goods:

TABLE NO. II

PRODUCTION SUMMARY FOR THE PLASTICS INDUSTRY: 1937-1939

	1939	1937	% Increase
Number of Establishments	38	34	11.8
Salaried Personnel	2081	1812	14.8
Salaries	$ 4,936,817	$ 4,205,542	17.4
Wage Earners (Year's Average)	6,966	7,283	- 4.0
Cost of Materials, Supplies, Fuel, Purchased Electricity and Contract Work	$40,564,000	$35,713,000	13.5
Value of Products	$77,653,000	$66,955,000	15.9
Wages	$ 9,840,000	$ 9,482,000	3.7

Source: U. S. Dept. of Commerce: Statistical Abstract, 1941

The following four tables indicate: (a) order and dollar volume of leading industries as of 1939; (b) total value of plastics products in recent years; (c) analysis of this value for 1939; (d) physical volume of plastics production in recent years. (1)

2. Corporate Size of Plastics Companies

Table Seven indicates comparable corporate figures relating to a cross section of independent plastics manufacturers throughout the country, indicating the number of employees, outstanding capital stock

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(1) See Tables III, IV, V, VI, pages 8 and 9

TABLE NO. III

REPRESENTATIVE IMPORTANT UNITED STATES INDUSTRIES: 1939

Industry	Value of Products ($ Million)
Iron, Steel & Machinery	11,570.
Farm Crops & Livestock	7,860.
Automobiles and Automotive Equipment	4,050.
Textiles and Fibres	3,930.
Allied Chemicals	3,730.
Meat Packing	2,470.
Stone, Clay and Glass	1,440.
Bakery Products	1,410.
Leather Products	1,390.
Tobacco and Products	1,320.
Petroleum	1,290.
Lumber and Timber	1,120.
Coal	915.
Rubber	900.
Plastics	77.6
Aluminum	65.

Source: U. S. Dept. of Commerce, Statistical Abstract, 1941

TABLE NO. IV

RELATIVE VALUE OF PLASTICS PRODUCTS BY YEARS

Year	Value of Products ($Million)
1933	25.0
1935	44.0
1937	66.9
1939	77.6

Source: Simonds, H. K., Industrial Plastics, Pitman (N.Y. 1941) p. 15

TABLE NO. V

ANALYSIS OF PLASTICS VALUES: 1939

Plastic Product	Millions of Dollars		
Synthetic Resins (Phenolic, Urea):			
Laminated Products:	20.6		
Molded or Cast:	34.3	54.9	
Cellulose Compounds:		19.0	73.9
Miscellaneous Unaccounted For:			3.7
Total Value (as in Tables III and IV)			77.6

Source: Simonds, H. K., Industrial Plastics, Pitman (N.Y. 1941) p. 222

TABLE NO. VI

ADVANCES IN VOLUME PRODUCTION

Year	Volume (lbs.)
1929	33,000,000
1935	95,000,000
1939	128,000,000

Source: Simonds, H. K., Industrial Plastics, Pitman (N.Y. 1941) p. 16

and apparent net sales and operating profit for 1939 and 1940. Large nationally known companies which are subsidiaries of leading chemical corporations whose consolidated annual statements conceal the figures pertaining to plastics are not suitable examples for comparison. (1)

(1) See Table VII, page 10

TABLE NO. VII

CORPORATE DATA COVERING TEN REPRESENTATIVE PLASTICS MANUFACTURING COMPANIES

Item	Name of Company	Trade Name of Product	Plastics Type	Year Inc.	Par Value Outstanding Cap. Stock (Thousands of Dollars)	Net Sales (Thousands) 1940	Net Sales (Thousands) 1939	Operat. Prof. (Thousands) 1940	Operat. Prof. (Thousands) 1939	Employees 1940
1	Catalin Corp. of America	Catalin	Phenolic Resins	1929	536.	1830.	1760.	210.	170.	311
2	Celluloid Corp.	Celluloid Lumarith	Cell.Nit. Cell. Acet.	1890	2920. 48433 Sh. N.P. Pref.	6940.	6590.	430.	280.	1545
3	Chicago Molded Products Corp.	(Finished Moldings)	Miscel.	1919	130.	1660.	1470.	120.	80.	574
4	Continental Diamond Fibre Co. of America	Celeron Dilecto	Phenolics	1929	1970.	6310.	5020.	650.	160.	2000
5	Durez Plastics & Chemicals Co., Inc.	Durez	Synthetic Phenolics	1939 Reorg.	1360.	----	----	---	---	410
6	Formica Insulation Company	Formica	Phenolic Laminates	1913	148000 Sh. N.P. Com.	4250.	2890.	610.	310.	706
7	Haskelite Mfg. Corp.	Haskelite	Molded Plywood	1917	579.	3580.	1010.	520.	140.	323
8	Heyden Chemical Corp.	-----	Gen. Chem.	1925	1560.	----	----	1480.	1100.	325
9	Polaroid Corp.	Polaroid	Cell.Acet.	1937	869.	710.	760.	----	----	190
10	Richardson Co.	Insurok Ebrok	Misc.Plast.	1919	200000 Sh. N.P.	----	----	1090.	970.	1373

Source: Compiled from Moody's Industrials 1941

3. Growth of Raw Materials

The gradual change in the emphasis of certain plastics materials within the industry is shown by the reduction in volume of nitrocellulose and the rise of other plastics such as cellulose acetate. Although nitrocellulose was for years the leading type of plastic product it was superseded in volume after 1937 by other plastics. Between 1933 and 1939 cellulose acetate increased from 2,875,000 lbs. to 20,790,000 lbs. and in 1940 to 23,800,000 lbs. (1) Phenol and Cresol resins together, while increasing from 4,660,000 lbs. in 1920 to nearly 90,000,000 lbs. in 1937, accomplished a reduction in pound price from 73 cents to 19 cents. (2) At the present time the U. S. Bureau of the Census, most reliable source of plastics statistics, does not indicate the entire field of plastics products owing to the many small plastics parts incorporated as parts of other listed products.

4. Comparative Materials Costs

The best common comparison of costs of materials can be made by indicating pound prices of semi-finished products available for further fabricating into final products, although a cubic volume cost comparison might be more conclusive owing to variations in density of the various materials covered. A pound of light material could produce more goods than a pound of heavy material.

In the following table of pound prices two lists are given for plastics ingredients, one the raw chemicals, the other, plastics powders ready for molders. Refined pig-metal prices and a few finished material

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(1) Modern Plastics, Vol. 18, No. 9, May 1941, pp. 50 and 98.
(2) Ibid.

TABLE NO. VIII

REPRESENTATIVE MATERIALS PRICES PER POUND - 1941-1942

Material	Price	Material	Price
A. PLASTICS RAW CHEMICALS		B. PROCESSED PLASTIC POWDERS	
Butyric Acid	$0.22	Casein	$0.15
Butyl Acetate	.14	Cellulose Acetate	.55
Butyl Aldehyde	.16	Furfural (L)	.10
Ethyl Acetate	.11	Furfural (C)	.20
Formaldehyde	.055	Polystyrene	.80
Furfural Alcohol	.20	Urea Phenolic (Av.)	.36
Methyl Acetate	.09		
Phenol	.12		
Synthetic Methanol	.345		
Urea (Impure)	.04		
C. PIG METALS		D. MISCEL. FINISHED BLDG. MAT.	
Aluminum	.15	Steel Shapes	.021
Copper	.12	Steel Sheets (Elect. Grade)	.06
Lead	.06	Lath & Plaster (Comb.)	.06
Pig Iron	.014	Fir Plywood	.03
Scrap Iron	.010	Fir Plywood (Resin)	.035
Tin	.52	Hard Maple	.013
Zinc	.08	White Oak	.009
		Red Oak	.011

Sources: (A) Chemical and Engineering News : June 1942
(B) Simonds, H. K., Industrial Plastics, Pitman, (N.Y. 1941)
(C) Iron Age : July 1942
(D) Engineering News Record : July 1942

prices are given. Although not all the prices are for the same quarter of the year they indicate relative values and show that chemical processing adds considerably more to plastics materials costs than to other materials costs, and makes the plastics price range above that of older materials finished and ready for final fabrication.

These prices indicate the cost disadvantages of plastics raw materials on a strictly pound basis as compared with raw products of more established industries; for example, commercial aluminum costs $0.15 per pound but cellulose acetate powder, which might be later molded into a product to compete with an aluminum product, costs $0.55 per pound. Given raw plastics materials for molding purposes must compete within the industry on a price basis with other plastics materials for a given purpose. The molded products must then compete with other established materials for a given mechanical use, or consumer use. Obviously, however, the mechanical requirements of the final commodity, the processing cost, and certain marketing possibilities for the commodity will help to determine the material chosen for the product.

Comparative figures for the plastics industry are hard to obtain or to correlate at the present time because of (a) the newness of the industry; (b) the need for clarification of the products to be represented by a given statistic; (c) the variety of authorities giving figures.

D. British Plastics

With reference to raw materials some interesting figures are available regarding the British plastics industry.(1) It is stated that as of 1941 the English industry required approximately 3000 tons of cotton linters to supply its cotton branch of cellulose ester plastics, and

(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) pp. 38-45

although the British Empire could supply this field, most of the linters were imported from America. The wood pulp branch of the cellulose industry also depended on America for its supply of pulp since a more pure variety than the Swedish pulp was available here. At best, however, pulp cellulose is regarded as inferior to cotton.

Yarsley and Couzens are concerned about the necessity for importation of raw materials for plastics purposes and, after indicating that development of an adequate forest acreage in England is impractical, they would encourage the growth at home of the following agricultural fibres based on per cent of cellulose content:(1)

Flax	71-83%	Bamboo	53%
Hemp	78	Esparto	46-50
Jute	61-64	Wheat Straw	44-51

It is not explained how some of the tropical fibres can be adapted to the climate of the British Isles but presumably chemical treatments and advances in manufacturing methods are implied by these writers in their plea for further research. The fibres listed are elements of the group of plastics known as furfurals which will be described at a later point. (2)

The possibilities of cornstalks and synthetic cellulose were also considered, but, since the synthetic variety requires sugar, probably little help could be offered to the industry from this latter source at the present time. Cornstalk cellulose was found practical at Iowa State University and this material is rated among the present sources. (3)

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(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 39
(2) See page 27 of this thesis
(3) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 39

The foregoing cellulose content figures are of interest in indicating possible effects and demands on agricultural products from the plastics industry in the future.

English acid requirements for cellulose treatment are supplied by Canada which provides acetic acid. Sulphuric acid, however, is made from imported Spanish pyrite.

Third and fourth elements required in the cellulose plastics field are known as solvents and plasticizers. These enable the other materials to be combined for plastics manufacture. The principal solvent is acetone made from alcohol. This is available in England from a catalytic process starting with alcohol. Plasticizers consisting of camphor, also a number of phosphate esters and alkyl phthalates, and glycerin, are also produced in England as the result of English experience with failure of Japanese and German sources prior to the first World War. Turpentine, however, which is the base for camphor, is imported largely from America, but the authors state that as of 1941 the high English tariff on turpentine was a detriment to the camphor business.

Other important elements in the plastics industry such as phenols and acetylene are or could be adequately provided by England's natural coal and limestone deposits and there are good possibilities for development of the necessary chemical organizations to produce these plastics essentials. Rennet Casein for plastics is also being developed slowly in England and more slowly in the United States.

E. Points of Economic Significance

The summary of the economic features of the plastics industry in England emphasizes the interdependence of nations upon each other for

raw materials and shows the extensive internal development necessary for a country to become independent with respect to raw materials. America is prominent as a source of raw materials for the plastics industry of the world as it is in certain other industries and, incidentally, considerable credit is given to America as a source of quality materials as well as for volume. Another significant point is the long line of materials in the chemical and plastics industries. To get one product, essential to the industry, it is necessary to treat, isolate, or combine chemically several other materials.

F. War Economy and Raw Materials in America

With reference to the effect of wars on this country's economy it is significant that many of the plastics chemicals are in some form directly required in explosives such as cotton and cellulose, and their need for armaments manufacture directly affects the plastics industry. On the other hand, plastics for mechanical parts not subject to great stress, and for essential war conveniences would release stronger metallic materials for the heavy duty equipment of war. Some attempts have been made recently in the United States to use plastics for fuse parts for shell manufacture but in this case the materials were not sufficiently strong and the War Department has requested further research.

1. Materials Classification

Reliable supply and economical use of raw materials during war requires their classification as (a) Strategic; (b) Critical; (c) Essential. The first group consists of imported materials; the second, of adequate domestic materials requiring controlled distribution; the third, of adequate domestic materials requiring cooperative use.

With reference to those minerals affecting plastics in a war economy the strategic list in America includes eleven: Antimony, Chromium, Diamonds, Manganese, Mercury, Mica, Nickel, Quartz, Tin, and Tungsten; also Rubber. The critical list contains six: Aluminum, Asbestos, Graphite, Iodine, Optical Glass, and Vanadium. The essential list contains twenty-three minerals but only four are related to plastics in manufacture or utility competition: Abrasives, Chlorine, Nitrogen Compounds, and Petroleum. (1)

Upon inspection the first list shows chromium and nickel, elements much used in ornamental stainless steel trim and for plastics plating. This type of trim is in direct competition in peace times with extruded plastics for interior finish for restaurant, theater, and furniture decorations and equipment. For outside purposes steel has the advantage. Diamond grains are mixed with plastics materials for grinding and finishing equipment, as is mica, which also has advantages in electrical plastics. Quartz is related to the glass industry which will be a leading competitor for plastics in architecture. The glass industry has special significance today in replacing tin and has long been a cheap medium for common or artisticly colored containers.

Among the critical materials aluminum has been a competitor of plastics for kitchen utensils, architectural strip and miscellaneous light-weight purposes. Asbestos is a direct element in cold molded plastics for heat, wear and water resistance. Graphite is a filler in the plastics industry. Optical glass encounters increasing competition from Styrene and Methyl Methacrylate plastics in ordinary times.

(1) Tyler, P. M., Industry Goes to War, (Symposium by C. E. Fraser and S. F. Teele), McGraw Hill (N.Y. 1941) pp. 40-48

As for the third list, the few items applicable to plastics are noteworthy principally as chemical elements which must be combined with other elements to produce commercial materials.

It is evident, therefore, that if, in war times, these materials and elements are declared to be of prime importance, then all industries dependent upon them are intensely affected. Certain industries in this group wholly dependent on these materials must either convert to full scale war work or close down. Those having less important outlets for products must concentrate on the more important outlets.

2. Sources of Materials

World sources for a few of the strategic materials are as follows: Chromite comes principally from South Africa, Russia and Turkey. The United States uses about two-thirds of the world output. Diamonds from Rhodesia and the Belgian Congo give England a large claim on industrial supply but the United States is a leading user. Mica splittings, which constitute the real mica problem, are imported principally from India where only 2% of its output is in this highly prized form. Sources for ground mica, common in certain thermoset plastics, is not considered to be a problem. Eighty-five per cent of world production of nickel is found in Canada and five per cent in Caledonia. Its principal use has been in the automotive and railroad industries and for kitchen trim purposes.

Minerals, as related to rubber, apply to the synthetic varieties. Trade names of those rubber-like plastics which are more commonly found in suspenders, belts, etc., are Neoprene, Thiokol, and Koroseal. Ameripol is another type now being used for tires. The elements of the synthetics--

coal, oil, gas, air, water, lime, salt and sulphur--abound in America and offer no raw material problem. Many of these are also the sources of plastics chemicals.

G. Future Peace Time Development of the Plastics Industry

In summarizing the future position of the United States with respect to minerals Tyler says this country is the world's largest producer, consumer, and distributor of minerals and their products, and could be made independent in this field for many years could it but acquire a stock pile of tin, mica, quartz, industrial diamonds, and some ferro-alloying materials. (1) This country has, however, emphasized research for new applications to exploit those raw materials which are exceptionally abundant. This tends to offset the waste of some less abundant resources. The plastics chemists are among the leaders in the materials development field. Many new developments in synthetics are expected to provide work for those displaced when present mines become exhausted.

During normal peace times, therefore, the plastics industry will increase demand for farm fibre and grain-chaff products; coal and forest products; chemical production of elemental acids, bases, and compounds; mechanical production of atmospheric nitrogen; alloy steels and machine tools; plant construction; improved distribution and clerical methods; public demand for attractive and useful cheap products. It will encourage research and the discovery, adaptation and application of new materials. On the other hand, it will require definite governmental policy on forestry, plant and agricultural uses, reservations and public lands and further attention to soil conservation. Modern emphasis will

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(1) Tyler, P. M., Industry Goes to War, (Symposium by C. E. Frazer and S. F. Teele) McGraw Hill, (N. Y. 1941), p. 51

coal, oil, gas, air, water, lime, salt and sulphur--abound in America and offer no raw material problem. Many of these are also the sources of plastics chemicals.

C. *Future Peace Time Development of the Plastics Industry*

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(1) Tyler, P. M., *Industry Goes to War*, (Symposium by J. G. Frazer and S. J. Teele) McGraw Hill, (N. Y. 1941), p. 51

be given to the theory that land is wealth. The industry may work adversely on the small wood products and metal trim makers and miscellaneous small products, on steel and lumber required for these products and for architectural elements which for years have been made from former standard basic materials. Glass and porcelain--and certain fabrics and yard goods--may also be among raw products affected by plastics progress.

Many plants will be able to change their line to accommodate the new products and even transfer their emphasis to the actual production of plastics wares, and while many of those concerns which do not adapt themselves to these changes may fail, it is also true that those which hold out during the change may profit in the end by being the sole survivors of their field and acquiring the entire remaining market for the older products.

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SECTION II - PLASTIC MATERIALS

A. The Theoretically Perfect Plastic

A. F. Randolph, after giving the proposed definition previously quoted on page 3, acknowledges that no one material could have all the desirable qualities to the maximum degree, but he describes the following among others as important qualities for the plastic to possess: Low cost per volume; low specific gravity; light weight; ease of fabrication and machining; high softening and low molding temperatures; strength and toughness; hardness; high index of refraction and light transmission; a clear and colorless base material; low moisture absorption; chemical stability; freedom from odor and taste; good electrical properties; minimum deterioration characteristics; fire resistance. (1)

It is clear that such a group of qualities would be difficult to obtain in one material. The important point is that practical products would be unlikely to require all of them, hence the choice of a material would depend upon the purpose of the product. Fortunately, therefore, as new materials are developed certain outstanding qualities and economies may be emphasized resulting in the superseding of common existing materials and reduction of new-product cost. The former material would then be available for other suitable uses. Since plastics are synthetic chemical materials the possibilities for such future developments are obviously more promising than the development of new minerals, for example.

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On the other hand, the limitations of the present group of plastics make compromises necessary when choosing a material. It might be necessary, for instance, to sacrifice best molding qualities in order to obtain best electrical features. Transparent cast phenolics are more expensive than Methyl Methacrylate products but may be more beautiful for the use at hand. In today's group each material has its own characteristics for given purposes and the perfect plastic remains theoretical, perhaps to be evolved as a practical material of the future.

Since an actually perfect plastic cannot be found today which would eliminate all thought and consideration as to choice of materials, one must be content with a careful consideration of those materials which are available. Brief glimpses of the composition and merits of these materials will be presented, therefore, to give an idea of the materials field from which commercial products may be chosen.

B. Types of Plastic Materials

The materials of plastics are essentially chemicals with the assistance of so-called fillers or binders, the purposes of which will be shown in the discussion of manufacturing methods, or with the aid of other well-known basic materials such as wood and metals. Many basic materials known for hundreds of years, like brass or even steel, are also essentially the result of chemical reactions. Plastics, however, being materials which come from elements more romantically regarded as "chemicals", are associated with the chemical industry. Many of the elements of plastics when treated in other ways and combined with other elements are the ingredients of everyday products which are not plastics.

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1. Classification

Plastics products are of two main classifications: Thermosetting, which in the final state for public consumption are rigid and, within definite limits, indestructible; or Thermoplastic, which, although sold in a definite form for a specific purpose, may become warped or misshapen upon application of sufficient heat. Certain plastic products such as celluloid will actually burn.

Thermosetting materials are particularly adapted to cast products which, when completed, are definite units like ferrous or non-ferrous alloys; or to hard homogeneous sheets useful as semi-finished raw materials for fabrication or for sheet uses.

Thermoplastic products may also be cast and their properties for specific purposes may justify such castings in preference to thermoset castings. Thermosplastics have an advantage when produced in sheet form in that by reheating, pieces of the sheet may be molded by press and die to form what appears to be a casting, this end product being the final commercial product. It can, however, be deformed and ruined for its original purpose by inadvertent application of excessive heat by the consumer.

Other plastic products of different chemical composition but containing the same elements form flexible cloth-like or rubber-like materials suitable for curtains and rain-coats. Certain other materials such as hard rubber, shellac and natural resins are properly classed as plastics. The field for plastics is so large that many commercial applications must be ignored here as irrelevant to the principal object of this thesis, such as signal parts, radio equipment, handles on large machinery, brake couplings, camera parts, process stirring equipment and woolen mill bobbins.

2. Limitation of Scope of Thesis

The materials to be considered will, therefore, be limited to those used in construction, display or for commercial containers and applicable primarily as moldings, castings, laminations, or extrusions; in general, substantial and durable products. It should be noted, however, that the raw material for these fabricated products is previously prepared by the chemical industry from chemical elements and delivered by it in powder, liquid or sheet form to manufacturers of final products.

With this principal limitation we shall proceed to a brief comparison of plastic materials. Simonds classifies the newer plastics in this manner: (1)

Thermosetting:	Thermoplastic:	Thermoplastic (cont'd):
Phenolic Group	Cellulose Group	Vinyl Group
Phenol-Formaldehyde Resin	Cellulose Acetate Binder	Vinyl Resin
Phenol-Furfurral Resin	Cellulose Nitrate Binder	Styrene Resin
		Acrylic Resin
Urea Group	Protein Group	Indene Group
Urea-Formaldehyde Resin	Casein Binder	Indene Resin
Thiourea-Formaldehyde Resin	Soy Bean Binder	
Urea-Melamine Resin		
	Alkyd Group	
	Alkyd Resin	

C. Thermosetting Plastics

The principal thermosetting plastics include those of phenolic or urea bases. The phenolic base molded products consisting mainly of Bakelite, Durez, Durite, Indur, Makelot, or Resinox (manufacturers' trade names) are composed of phenol (carbolic acid) and formaldehyde which are combined to form a resin which, during later processing as a molder's raw material, can be heat-softened for molding. The final cooling then produces

(1) Simonds, H. R., Industrial Plastics, Pitman, (N.Y. 1941), pp. 5-6

the practically indestructible set product. The molded product, however, contains a filler of wood flour, asbestos, paper, graphite, or others, which affect the physical characteristics of the product, and the type and proportion of filler depends on the ultimate use for the product. The mixture of resin and filler is cured in the mold for forty-five seconds to twelve minutes at a predesignated heat and removed hot as the final product. Exceptionally smooth exterior finish can be obtained by water-cooling the mold before removal of the product. The relative physical characteristics of this product as compared with other plastic products can be most easily noted on the chart of plastics comparisons at the end of this thesis.

1. Molded Phenolics

In the field of molded phenolics there are five classes based on the filler material. First, Class "A" wood flour, is used for lightness, superior surface finish, high dielectric strength, and to some extent mechanical strength; Class "B", asbestos filler, for water, oil, weak acid and heat resisting properties and for maintenance of original shape; some wood flour may be included; Class "C", fabric fillers of three types, for impact strength and toughness; Class "D", practically pure phenolic, for color transparency, hardness, heat resistance, lightness, form, and electrical properties; Class "E", special products to meet special requirements. Despite the special water resistance of Class "B", water is particularly harmful to all phenolic plastics.

2. Laminated Phenolics

The laminated phenolics differ from the molded in that paper or textile sheets instead of filler powders are used for the filler

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2. <u>Laminated Phenolics</u>

The laminated phenolics differ from the molded in that paper or textile sheets instead of filler powders are used for the filler

materials, creating an end product in sheet, rod or tube form suitable for machining to make an industrial or consumer product. More time is required for laminating than for molding, the process both impregnating and drying the filler simultaneously in a hydraulic press. Rods and tubes are made by wrapping impregnated sheets on mandrels under pressure or by comparatively loose wrapping followed by pressure in molds. Heat treatment in ovens completes this process. Molded products from laminated material require a series of progressively smaller molds, each stage bringing the product nearer to its final form. Sheets are produced in six recognized grades, four of which have paper bases and one canvass, the last linen. The price of these is determined principally by the proportion of resin in the product. Laminated phenolics are adapted to chemical containers and barrels, silent gears such as Textolite or Formica, table tops and artificial-grain wall panels. The principal properties are strength, flexibility, oil and water resistance, finish, and electrical properties.

3. Cast Phenolics

Yet another type of phenolic formaldehyde products are the castings. These are made in lead molds from phenolic ingredients without fillers. The product, which may be transparent, translucent, or opaque and colored, is made from the resin which has been carefully heat controlled up to twenty-four hours to form a viscous resin which is immediately poured into the molds from hand ladles. The physical properties for final machining resemble wood or brass, which allows the final product to be processed through a machine shop in a similar manner to metal products. The material possesses many of the qualities mentioned

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for the other phenolic classes but may also be shaped or expanded by oil treatment at 250° F., thus resembling a thermoplastic. This material is highly suitable for jewelry and high lustre products, or for cutlery handles, clock cases, and others, but not for products where fixed dimensions and strength are important as in the molded products group. These castings harden with time and are relatively more expensive than moldings.

4. Furfurals

This very interesting group of plastic products could be called "the farmers' delight" since it is the one which requires the various waste products of the cereal grain and cereals manufacturing industries, plus other non-edible farm and garden products. Among the chaff used for this binder are oat, coffee, and cotton seed husks, bran, soy bean, sunflower seeds, straw, and cornstalks, some of which were mentioned in the discussion of the British raw material sources. The chief American material is oat husks. World production today is about 35,000 tons per year of all furfural materials and considerable progress is being made toward raw material price reduction.

Furfural compounds, bran and oil, are essentially aldehydes, therefore substituting for formaldehyde in combination with phenol to form another class of phenolic plastic material, but the chemical reaction of this particular phenolic requires a longer time than typical phenolics of the Bakelite variety.

Mechanically, furfurals are dark colored and largely unsuited to bright coloring but are heat resistant, fairly strong and to a degree acid resistant. They strengthen and darken with age and exposure to

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Mechanically, furfurals are dark colored and largely unsuited to bright coloring but are heat resistant, fairly strong and to a degree acid resistant. They discolor and deform with age and exposure to

sunlight. Furfurals resemble other phenolics in a general way, are subject to the same manufacturing methods and are suited to sheet and molded forms of products. They are also suitable for injection molding, thereby differing from Bakelite phenolics which do not work very effectively in injection molding machines. As will be brought out later, injection molding is the most promising type for mass production of plastics molded products and furfurals will, therefore, have considerable opportunity for cheaper production costs. This type of plastic is much used for mechanically strong products, for electrical, asbestos wear-resisting and grinding-wheel purposes.

5. Ureas

Leaving the phenolic base thermoset plastics we come to the urea base thermoset and its satelite Melamine. Urea and formaldehyde constitute this type which has the advantage of great color variety, also translucency, a property suitable for electric light fixture reflectors. It is three times as expensive as plain black phenolic due partly to extra care needed in keeping molds clean to prevent scratches and specks in the product. This material is not as durable as molded phenolic since it tends to be water absorbent, to char at relatively low temperatures, and may warp or check with time. Delicate colors fade when used in ureas. The material is fairly resistant to common chemicals and is adapted to cosmetic containers and other thin-walled items not subjected to heat during ordinary use.

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Both of these materials are also known as Bakelite, Beetleware, or Plaskon.

The foregoing phenolics, ureas, and furfurals constitute almost the entire thermoset field at the present time and it is necessary, therefore, to consider thermoplastics from this point on.

D. Thermoplastic Plastics

Because many commonly used products are sold under trade names let us list the major thermoplastics with their trade names to familiarize ourselves from the outset with the basic materials behind the magic names in popular advertising. Among the best known are:

1. Cellulose Acetate:	Bakelite, Lumarith, Fibestos, Fibreloid, Nixonite, Plastacele, Tenite
2. Cellulose Acetate Butyrate:	Tenite II
3. Cellulose Nitrate:	Celluloid, Pyraheel, Pyralin, Resisto
4. Ethyl Cellulose:	Ethocel, Golden Rule
5. Methyl Methacrylate:	Crystalite, Lucite, Plexiglas
6. Styrene & Polystyrene:	Bakelite, Styron, Lustron
7. Vinyl:	Vinylite, Alvar, Butvar, Gelva, Vinyon
8. Nylon:	Nylon
9. Indene:	Cumarone, Cumar, Neville

These materials are particularly adapted to the molding processes. This list emphasizes the commonly used name of Bakelite, which, although most frequently applied to thermoset products, has, nevertheless, been applied to certain thermoplastic materials due to its early connection with general plastics. This double use may persist for some time but the name will eventually become associated with a definite type.

1. Cellulose Acetate

Cellulose Acetate is a molder's material resulting from cotton linters treated with acetic acid and acetic anhydride, the final composition containing plasticizers and dyes. The initial application of heat produces

the plastic, a material of the same composition as the powdered ingredients. Thus only the form has changed, whereas in the phenol and urea groups a new material results. The product is removed from the mold cold. The outstanding advantages are machinability, resilience, high polish, and toughness which is necessary in thin-walled products such as powder-puff boxes. It is not adapted to water containers and will lose shape at 150° F., but is fire-resistant although not fireproof. Special care is required where the material is associated with other chemical products, due to chemical reactions. This is a common difficulty in all plastics, particularly thermoplastics. The great value of acetates in comparison with other plastics is the variety of colors and mixed color effects possible with this material. Highest costs occur in the mixed colors. Minimum raw material prices require a guarantee of about 5000 pounds of any single color to obtain a standard price. Special prices are charged in the trade for smaller amounts.

2. Butyrate

Butyrate is made from compositions of butyric and acetic acids. It resembles acetate but is less absorbent and, having a lower plasticizer content, will withstand higher temperatures and humidities. It is resistant to fire, light-fading and weak acids, but will decompose in alkalies and alcohol.

3. Cellulose Nitrate

Cellulose Nitrate, the well-known celluloid, is the oldest commercial plastic. Celluloid advantages are toughness, water resistance, moldability, machinability and beauty. It is largely superseded by cellulose acetate since celluloid is highly inflammable.

4. Ethyl Cellulose

Ethyl Cellulose resembles cellulose acetate in appearance but has excellent dielectric, toughness, and fire resistant qualities. It is flexible at below zero temperatures and is not affected by alkalies.

5. Methyl Methacrylate

This plastic is most common in beautiful transparent objects. It is one of the acrylic resins of particular value in optical work and in place of shatter-proof glass. It can be molded from powders, cast, or obtained in rods and sheets. As a liquid it flows slowly and thin castings are, therefore, not practical. The end product hardens slowly, thus increasing manufacturing cost; it shrinks for indefinite periods after completion, but is not otherwise affected by age and is resistant to acid and light effects. Color values to rival transparent phenolics are predicted for the future.

6. Polystyrene

This outstanding electrical plastic is particularly useful for items in short wave and television work where permanence of composition, shape and size are important. It is also moisture-proof, acid-resistant, hard and strong, and is obtainable mainly in powder form for injection molding. Its uses for domestic purposes are still under development.

7. Vinyls

These plastics are related to styrenes but consist, as an entity, of a composition of vinyl acetate and vinyl chloride. Its properties resemble the styrenes except for the high electric qualities of the latter and it softens at 140° F., nearly 80° F. lower than styrene.

8. Nylon

Nylon resins as of 1941 were in process of commercial development but extruded tubes were then available. Strength, ductility, and heat resistance appear from published results to be outstanding qualities. (1) Electrical properties resemble those of the acrylics and butyrates and are not outstanding.

9. Indenes

Indene and Cumarone are elements of Naphtha which springs from coal tar. The two elements themselves are difficult to separate, hence both are found in indene plastics. Indene molding powders and certain indene varnishes are created through the treatment of naphtha with sulphuric acid followed by evaporation of the liquid. General characteristics of these plastics are water and acid resistance, dielectric strength, ease of molding, brittleness, and ability to combine with vinyls through the use of phenolic plasticizers to form new materials. They may be used for laminated plastics having a paper or other filler. Indenes are usually opaque of yellow, brown or black color but may also be a transparent yellow. Among the thirty or more indene plastics the practical use temperatures vary from 86° F. to 123° F. which limits their use to relatively cool climates and purposes.

This sketch of plastic properties merely highlights some of the merits and to a lesser degree the demerits of the field sufficient to give an acquaintance with the common trade names and a few uses for the products. Some of these products may be better emphasized by the following colored illustrations. (2)

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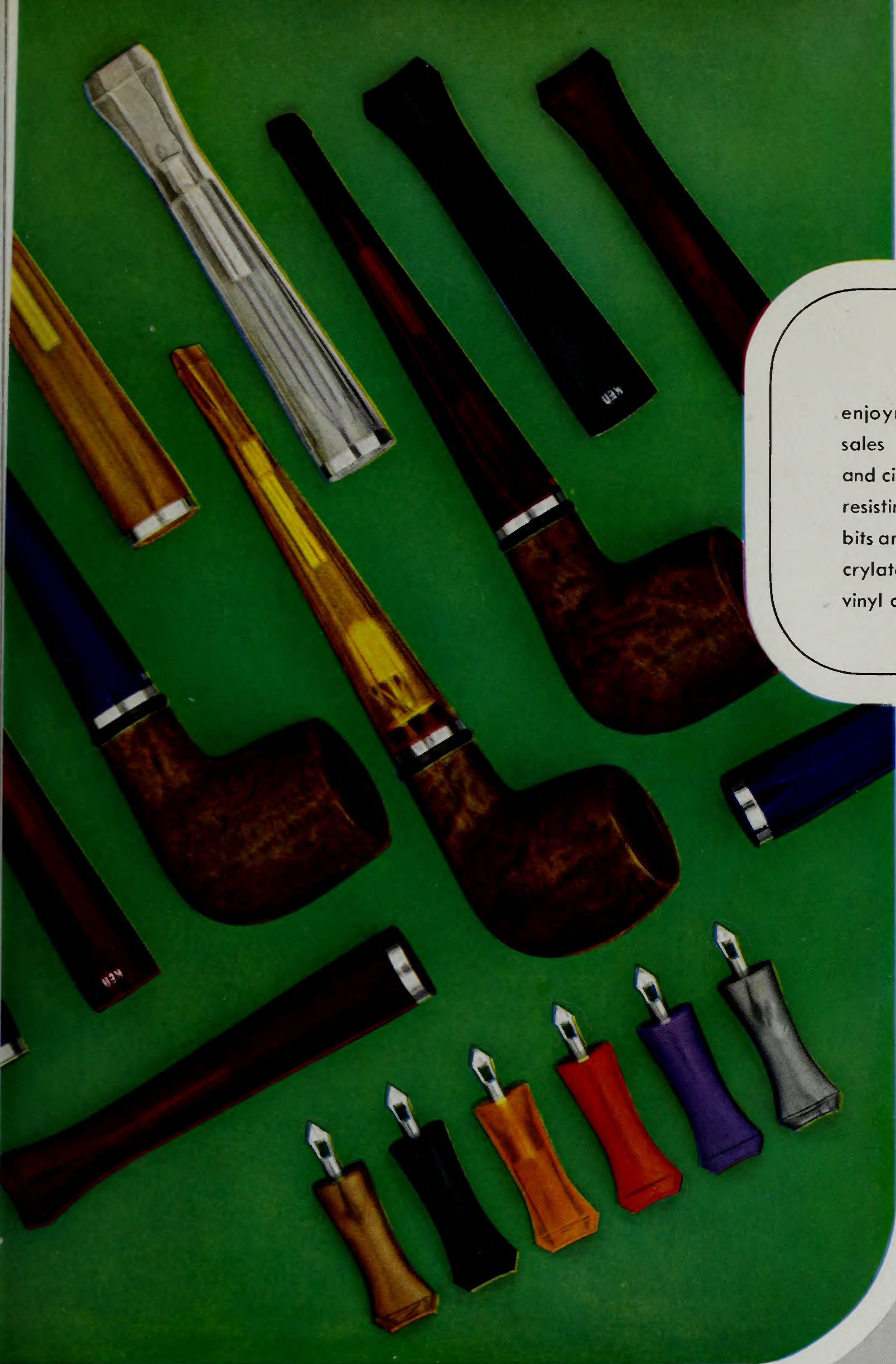
(1) Boonton Molding Co., Plastics Reference, Boonton Molding Co., (Boonton, N.J. 1941) p. 16

(2) Elmer E. Mills Corp., Injection Molded Plastics, Elmer E. Mills Corp. (Chicago 1942)



Increased smoking enjoyment and colorful eye and sales appeal are added to pipes and cigarette holders by these bite-resisting injection molded stems. Pipe bits are made of transparent methacrylates and also of soft, flexible vinyl copolymer.

*M*ony competitive problems of monufocturing ore answered economicolly by the modern method of injection molding. The thermostat housings, electric switch plates, fan housings ond meter, are but o few examples of this production efficiency. The beouty of plastic combined with the utility of the items has increosed consumer demond for these products.

Beauty of sight and of sound is combined in these plastic chime housings, artistically graced by ornate medallions and by lovely cameos, faithfully reproduced by injection molding to create new products of refinement and charm. High speed production and the resultant economies make these chime housings economically practical.

The field of injection molding is so flexible that novelty items, such as the banks illustrated, and everyday items for mass acceptance, can be produced to meet competitive demands and costs.

These plastic lamp base parts show how molded plastics effect product improvement. Precision molded in the desired color, they eliminate costly finishing operations and replace metals, so vitally important for defense. Plastics may solve your problems too.

Broom shoulders add to the life of the brooms; handle tips add to convenience, to give new sales appeal and value to the housewife's ordinary broom . . . the product conceived and produced within our own organization.

Precision injection molding for unit assembly is illustrated by these colorful musical instruments . . . Fidelity of tone is a function of exact fabrication. New products made commercially practical by this modern method of plastic fabrication and production.

Molded plastics . . . correctly designed and engineered . . . add beauty, utility and distinction with the additional value of all the advantages that this modern method of fabrication and these new materials provide.

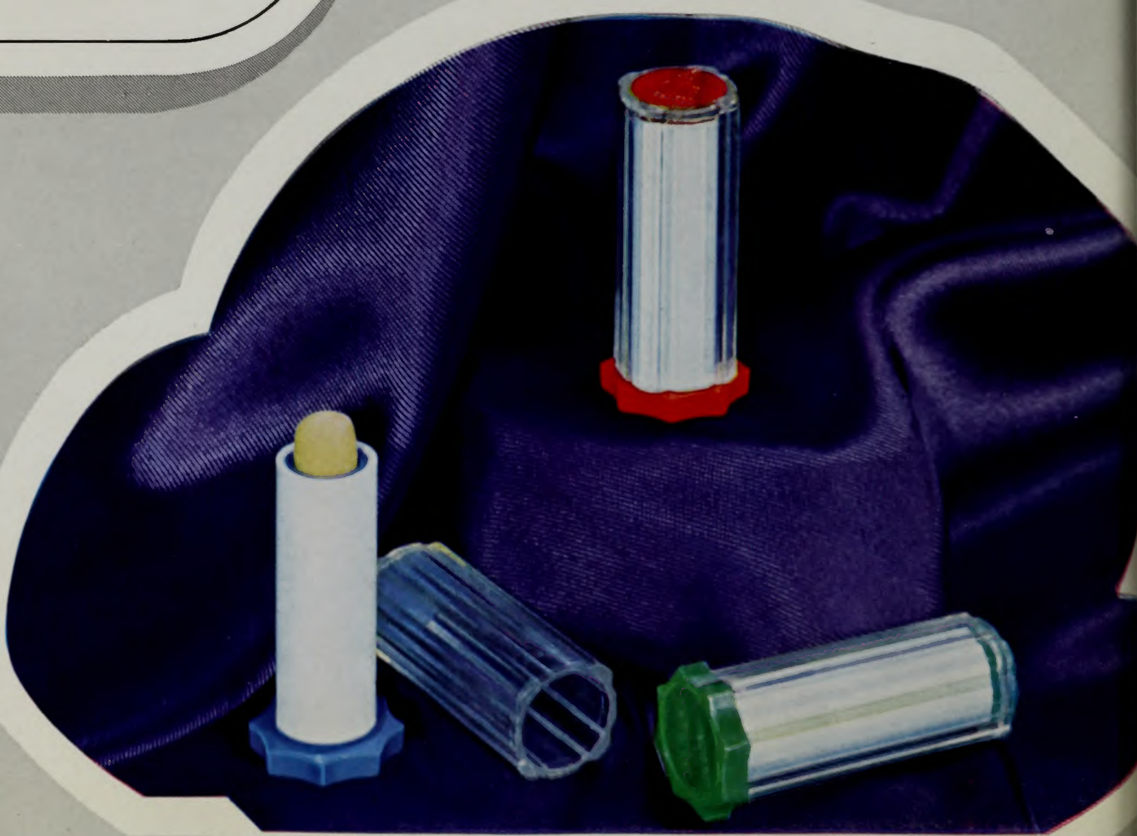


Fig. 8

E. Other Types of Plastics

There is another group of plastic products of a miscellaneous nature, some of which are not classified as plastics by some authorities, but since many do allow them to be included within the scope of the plastics industry they will be mentioned. The first is Lignin.

1. Lignin

The lignin base is derived from the treatment of wood chips under pressure and heat to remove sugars and other vegetable matters. This base may be used in wallboard compositions and for rods and tubes. It is not well adapted to molding since the molds require chilling, causing a processing cost which offsets the low raw material cost. Its properties resemble laminated phenolic. (1)

2. Caseins

Rennet casein plastic is made from milk curds and is produced in rods, sheets and tubes by the extrusion process. The casein curd is isolated, dried, ground, mixed with filler and color, and dampened before being fed to the extrusion machine where heat and pressure are applied. The extrusions are "horny". The final stage involves curing with formaldehyde. Soy-bean material is also used in the general class of casein plastics, some forms of which produce paint.

3. Hard Rubber

Hard rubber, long known in almost all walks of commerce and industry, is in some respects a plastic. Made from crude rubber and sulphur, vulcanized, it may be molded or machined as sheets, rods, or tubes. Molding may be done by pressing plastic rubber between tin blocks, by

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(1) See page 25

preforming before final pressing in lead molds, or by accurate vulcanizing in steel molds. Cost of the latter method is equivalent to cost of phenolic molding and, in general, cost is related to grade and percentage of rubber. Its advantages are strength, hardness and toughness, chemical and electrical resistance, heat insulation, color possibilities. Disadvantages include combustibility, cold flow, deterioration in sunlight, oil effects, sulphur attacks on metal and sulphur bloom on the rubber. Its manufacturing qualities are superior to phenolics for cast pieces containing small holes.

Synthetic rubbers or "Elastomers" derive their name from characteristics resembling rubber but this group is not actually rubber. Although treated and used in the same way as rubber these synthetics are in certain characteristics inferior. Their advantages are the correction of hard rubber faults, their resistance to oils, solvents, heat and cracking.

4. Shellac

Shellac or cheaper substitutes (copal and sandroc) is used as a binder with wood flour or other fillers to form an independent class of plastic product suitable for insulators, knobs, handles and buttons. The material is made on a roll like rubber, blanked while hot from the roll and later molded in hot molds, being removed from the molds after chilling. These products are accurate and smooth finished but colors are limited. The material is brittle and softens at 180° F.

Mention should be made of porcelain as an early plastic material now being superseded to some extent by the other types.

5. Cold Molded

The final material of the miscellaneous group is known as "Cold Molded" which would appear to be a descriptive adjective but is in fact a noun. This compound is produced in three binders: bitumen, cement, or resin, of which bitumen is most common. Other ingredients are oil, dryer, and asbestos. The bitumens are cheapest and weakest, the cements strongest, most fire-resistant, and more expensive than the other two. In the resin type, phenolic resins with binders are poured as cold liquids into pressure molds. The products are then finished by baking but since there is no pressure applied during the baking process which is comparable to the heat treating process of the phenolic types of plastics, cold molded plastics are weaker than standard-process phenolics. An important cold-molded product in the engineering field is "Transite", a cement binder product for sheets and pipe.

F. Plastic Materials Used in Electric Motors

An interesting example of the use of plastics in electrical applications is the electric motor which, depending on the actual electrical design characteristics, makes use of several types of plastics. In the following motor illustration phenolic Bakelite plastics are used for: (a) holding winding wire in place in the armature and stator slots (Top Sticks); (b) insulation between the brush holders (Brush Holder Ring); (c) insulated terminal support on outside of motor (Terminal Block); (d) miscellaneous washers; (e) push button for motor control; (f) insulated base for metal parts. Baked vinyl plastic insulation is found on copper magnet wire and cased flexible vinyl insulation on copper lead wire.

For item (a) Class "A" Bakelite of paper base laminate, or Class "B" with asbestos base is used depending on the amount of heat which will be developed in the motor windings. Higher temperatures require the heat-resisting qualities of asbestos fillers. In practice, the opinions of engineers differ and some prefer vulcanized fibre for this item, maintaining that it is better as a heat resistor than plastics.

In the case of item (b) paper base phenolic serves the purpose admirably since it is only required to insulate between several current-conducting elements which are attached directly to the ring. The terminal block located on the outside surface of the motor where the outside line connections are made must be large enough to accommodate all the electrical lugs and terminal posts. For medium sized motors black Class "A" molded Bakelite up to five-eighths inches thick may be used, being bolted directly to the iron frame of the motor.

For insulating washers between metal surfaces at various points in the motor subject to mechanical pressure, Class "C" fabric-base laminates are found. Push buttons for motor control may be of the Bakelite or Durez type replacing former hard rubber buttons, and either fabric- or paper-base phenolic may be used for small sub-bases for integral parts of the motor which are connected by internal wiring.

The winding wire and leads themselves may be plastic-insulated. For the actual winding of armature or stator, copper wire without fabric or rubber insulation is used and its necessary insulating may be an enamel of plastic base such as vinyl acetal. This treatment, applied in one or more coatings, reduces the total diameter of the insulated wire as compared with rubber and fabric insulated wire, thus requiring smaller

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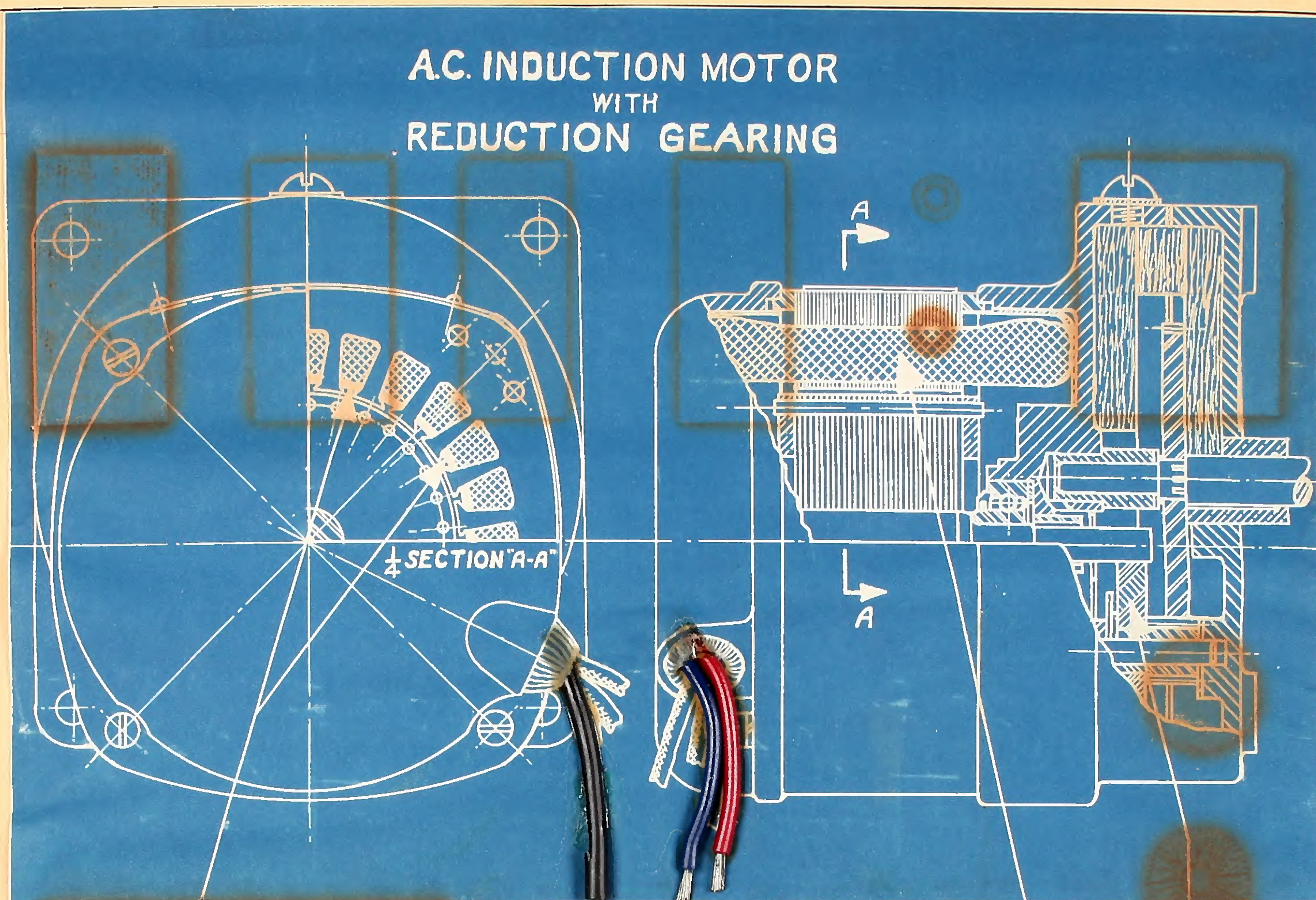
space for a given capacity. The motor can, therefore, be made smaller. One wire of this type is called "Formvar". (1) Lead wire for connecting the motor directly to other equipment when terminal blocks are not used, may be insulated with a flexible tube-like plastic covering which resists weather, oil, sunlight effects detrimental to rubber, and certain chemical effects. Performance of this plastic in these instances is better than the former rubber insulation, although the latter is superior for certain purposes. In some instances where expensive rubber is required as the primary insulation, it can be protected from acid or alkali attack by an outer coating of plastic similar to that indicated above. (2) One form of vinyl plastic lead insulation of this class is called "Okoseal".

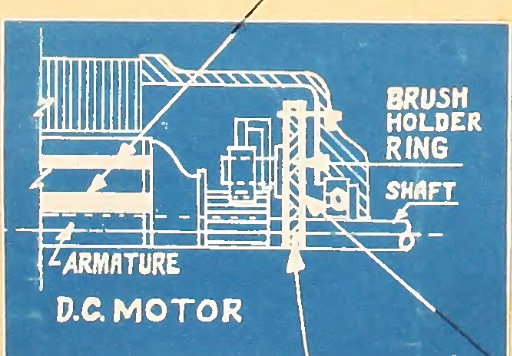
(1) Belden Manufacturing Co., Handbook No; 12, (Chicago, 1941) p. 11
(2) Simplex Wire & Cable Co., Simplex Manual, (Cambridge, 1940) p. 63



"Okoseal" Lead Insulation

"Flamenol" - Vinyl Lead Insulation

Top Stick - (Paper or Asbestos Filler). (For AC Stator above, and DC Armature below).



Types of Typical Fibre Top Sticks

"Formex" Vinyl wire coating for Winding Wire

"Formica" Type Fabric Laminate for gears

Grade "C" Laminated Fabric for insulated bases.

Two forms of Paper Laminates suitable for Brush Holder Rings

Black "Bakelite" Terminal Board

Laminated Fabric Washers

Wood-Filler Phenolic Insullation

SECTION III - PLASTICS CHEMISTRY AND MANUFACTURE

The foregoing indication of physical qualities of plastics and general reference to manufacturing methods and a few uses for the materials leaves the fundamental nature of plastics unanswered. Except for brief reference to technical combinations, nothing has been said about plastic composition.

A. Study in Organic Chemistry

The field of plastics is essentially an example of applied organic chemistry. Organic chemistry is the chemistry of carbon compounds. (1) Two elemental principles in the chemical development of plastic materials from which the products are made are "polymerization" and "condensation". Thus the common form of the name of certain plastic families is prefixed with "poly" as "polyvinyl" or "polystyrene" and these names are found generally in referring to these and some other products.

The prefix "poly", meaning, as usual, many or multi, derives in plastics from the 4-valence property of the carbon atoms which after applying two of their valences to other chemical material atoms have two free valences in the new molecule which attach themselves to the equivalent free carbon valences in neighboring molecules and form what are commonly known as "chains". In some respects the physical interrelation of these molecular chains of carbon compounds of the poly variety is responsible for the physical properties of the final plastic material. An example of polymerization occurs in the formation of polyethyl from

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(1) Webster's New International Dictionary, 2nd Ed., G. & C. Merriam Co., (Springfield 1938) p. 460

ethyl upon application of heat as follows:

$$(CH_2 = CH_2)_n \longrightarrow CH_2\ CH_2 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots CH_2\ CH_2$$

(This continues indefinitely while there remains enough ethyl to form the polymer).

Polymerized molecules are heavier than the individual molecules of the given substances because of the "joining" process just mentioned. When the thermosetting plastics of the polymer variety set after the final heating, the interwoven chains have formed a new material which cannot be broken down again. Phenolics and ureas are in this class.

The condensation process develops from so-called "esterification" by which "esters" or alkyl salts are produced. In plastics this will result from the combination of alcohol and acid, the condensation occurring through the formation of water as a by-product of the main chemical reaction. An example:

$$C_2H_5OH \quad + \quad HCl \quad \longrightarrow \quad C_2H_5Cl \quad + \quad H_2O$$

Ethyl Alcohol	Hydro-Chloric Acid	Ethyl Chloride	Water

Some plastics compositions involve a condensation stage followed by polymerization. These two principles may apply to either thermoset or thermoplastic materials but generally condensation is associated with thermoset. Many plastics reactions occur without either of these processes so that they are not essential to plastics formations, but are nevertheless of prime importance in the chemistry of the industry.

A third fundamental concerns cellulose plastics. Whereas molecular chains are synthetically built up by polymerization in certain other types of plastics materials, the celluloses contain the chains in natural state, each unit of the original chain being a Glucose molecule.

Due to the chemical composition of cellulose certain elements of the glucose molecules can be replaced by other chemical elements to form the cellulose plastics such as celluloid or cellulose acetate.

Certain of the physical properties of plastics are attributed to the chain principle. X-ray evidence is claimed to show that the chains of cellulose products are aligned in bunches called "micelles" in an orderly manner while, in other materials where X-rays have not shown the structure, it is assumed the chains have no orderly arrangement. The chains provide greater opportunity for molecular cohesion than would be found if the molecules were of separate units, hence the material does not melt upon heating but merely softens. The physical action of the chains upon one another is also credited with the reasonably elastic properties of the thermoplastics. Heat, however, affects the elasticity and if allowed to cool under stress the object retains its new shape. Plasticizers increase the elasticity by lubricating the chains so that they will slip by each other more easily when under stress.

With finished thermoset plastics condensation changes the properties so that the entire plastics product resembles one molecule of a new material which, having no constituent parts, cannot react to heat like a thermoplastic.

Toughness and impact resistance in cellulose is attributed to the blending properties of the chains. The Bakelite structure is similar to glass, although not so fragile, and therefore Bakelite is more brittle than cellulose. Polystyrene, whose chains follow no known pattern, is an example of an intermediate material between cellulose and Bakelite. These physical properties, among the plastics, are relative and there are limits even for cellulose.

The value of this molecular theory lies in the future development of new plastics, since, by proper combinations of materials or elements, plastics may be devised for given purposes which require definite physical characteristics.

Among the elementary series of chemicals entering into the various plastics materials are the following:

Methanes	
Paraffin Hydrocarbons	Amines
Ethylenes (Olefins)	Glycols
Alkylenes	Anhydrides
Aldehydes	Aromatics
Ketones	Benzenes
Fatty Acids	Phenols
	Cresols

Before proceeding with an outline of the manufacturing processes following our brief references to base materials, some attention should be given to filler and coloring materials.

1. Filler Materials

The field of assisting materials necessary to the final plastics product includes fillers, dyes, pigments, solvents, hardeners, lubricants, accelerators, and catalysts. The binders have been previously referred to and small attention need be given them at this point. (1)

In the discussion of the classes of phenolic base compounds fillers including wood flour, asbestos, and fabrics were mentioned. (2) Other present fillers include graphite, paper and mica. Commercial plastic wood is a composition of wood flour, cellulose nitrate and acetone, all of which have been mentioned as elements of the more stable

(1) See pages 3 and 22
(2) See page 25

plastics products. Similarly cold solder obtainable in hardware stores consists of cellulose, solvent, and powdered aluminum. Metal powders are now being considered as a plastics filler. The fillers serve at least three functions: to conserve resin; to prevent brittleness; to prevent surface cracks. Ultimately, therefore, in addition to mechanical considerations they reduce cost. Mica, fire resistant, works better with shellac bases than with phenolics. For heat insulating plastics, fillers of low density are desirable while for strength high density fillers are needed such as carbon-black and slate dust.

2. Coloring Materials

Coloring materials include earth pigments and dyes, the former requiring a greater volume than the latter, also proportionally more for coloring the clear plastics with delicate shades. Preferably bases are colored, usually by dyes, but colors may be added to the filler. Azo colors fade less than other types. Color raw materials prices vary from $.07 to $3.00 per pound.

3. Catalysts

The purpose of catalysts is to assist in the formation of a new material from base materials and the result obtained depends on the catalyst used. Catalysts can frequently be reclaimed and an example is found where alcohol, used to eliminate washing water from nitric and sulphuric-acid-treated linters in the nitrocellulose processing of cotton, is reclaimed to a large extent by mechanical means through presses and centrifuge machines. The alcohol is then reconcentrated for future use in the elimination of water from cellulose batches. (1)

(1) Yarsley, V. E. and Couzens, E. G., "Plastics", Allen Lane, (Harmondsworth, England, 1941) pp. 49-50

As another example, in the first stages of cellulose acetate production the cotton linters are treated with various acids, among which is concentrated sulphuric acid. The latter acid is a catalyst which remains in solution with remnants of the other materials in the process after the opaque cellulose acetate has been separated by the addition of large quantities of water. (1)

4. Miscellaneous

The other assisting elements have specific purposes. Thus to aid the flow of plastic materials into dies or to prevent the end product from sticking to the die such lubricants as stearates or wax are used. For quickening the setting time in the molds such accelerators as magnesia or lime are used in the case of phenolics, and oxalic acid or zinc chloride for the ureas.

Solvents have two features. First, in manufacturing, they are used to adapt the base material for the process, or to form a given related substance; and second, they must be understood in order to prevent decomposition of the finished product in subsequent uses of the item.

The various elements described above can be prepared by the chemical industry for the plastics molders and final product manufacturers in the form of molding powders which contain these essentials in fixed proportions for specific needs to produce certain physical properties in the product. The powders are the raw materials of the molding trade particularly in injection molding. Powders frequently are formed into "pills" of the proper amount for the particular plastics unit in

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(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane, (Harmondsworth, England, 1941) p. 53

order to prevent waste at the machine and to save the operator's time. This probably allows the use of cheaper grade operatives as well.

The proper combination of these ingredients, and their mixing, depends on the ultimate temperature at which the finished plastic will be used, the flow characteristics of the ingredient, the type of molding process which will be used, mold reactions, and the final color of the product. Standard mixtures and specifications of the American Society for Testing Materials are still being developed.

B. Manufacturing Methods

In addition to the foregoing background of chemical principles, association of raw materials, and general information regarding types and characteristics of common plastics products, it is desirable to learn a little about the mechanical process by which a couple of polymerized carbon compounds can be transformed into an attractive lighting reflector or other finished product.

The mechanical aspects of manufacturing shop processes involve materials, methods and machines. Materials have been covered in a brief way. (1) Methods and machines remain. Essentially the methods revolve around two main principles: molding and laminating. Molding includes casting as a secondary while laminating is a form of fabrication which also includes extrusion and occasionally rolling, these latter being terms borrowed from the steel and brass industries primarily.

1. Molding

The molding process requires the previous manufacture of a steel mold or die which is placed in a molding machine, the latter being designed

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(1) See pages 21-37

for compression, injection or cold molding, depending on the type of product desired, its material, and economy of cost.

The oldest standard method was compression molding in which the material was first heated in an oven, then poured into a hot multiple cavity mold, the cavities containing metal inserts which were to become a part of the finished casting. The mold or die was then immediately closed under pressure and water-cooled to set the product for removal. The need for more exact quantities of material in the mold to prevent waste led to the pilling system previously mentioned. (1) Modern compression molding methods provide for preheating of the pills before insertion in the mold-cavities, thus eliminating some of the waste while at the same time reducing equipment and unnecessary handling. Molding time is automatically controlled in today's machines and a bell rings when the time is up. The product is ejected from the mold after the mold is opened, by the action of compressed air which blows the piece into a "tote" box for transfer to the tumbling barrels where fins are removed from the product.

Compression molding is the most common method today, being almost mandatory for thermosetting types of plastics. For other types, however, injection molding, resembling in some respects the zinc and aluminum die-casting system of several years past, is fast developing. An important element in the production of plastics products is the mold, or die, and this will be explained presently. (2)

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(1) See page 43
(2) See page 50

2. Blow Molding

Another frequently used molding method is known as blow molding. This is adapted to products molded from previously made thermoplastic sheets. Two sheets are placed between the hollow halves of a mold and air is blown between them through a hollow needle to force the plastic into the mold cavities. Additional heat and mechanical pressure is then applied to join the two pieces of plastic, the needle having been previously removed.

3. Cold Molding

Cold molding, by which "Cold Molded" plastics products are made, is, as a production method, being superseded by compression molding. Its primary advantage is the production of heat resisting plastics. Progress is being made with heat resisting phenolics and it is expected that when the phenolics characteristics equal the cold molded, the latter product and method will become obsolete.

4. Injection Molding

A fast developing and most promising molding method is known as injection molding, the principle of which is illustrated in the figure on page 47.

This method is exemplified by a modern mass production machine process applicable largely to thermoplastic raw materials in powdered or granulated form. Powder and other ingredients are placed in a hopper at one end of the machine and are fed by a plunger to a steam or electrically heated cylinder where the powder becomes viscous and in the following plunger action is forced through an exit nozzle directly into the gate of the mold which is attached to the nozzle. The size of the nozzle

orifice determines the supply of material. The mold is water-chilled by the machine, thus setting the product which is ejected when the mold is opened, the opening also being a part of the mechanical operation of the

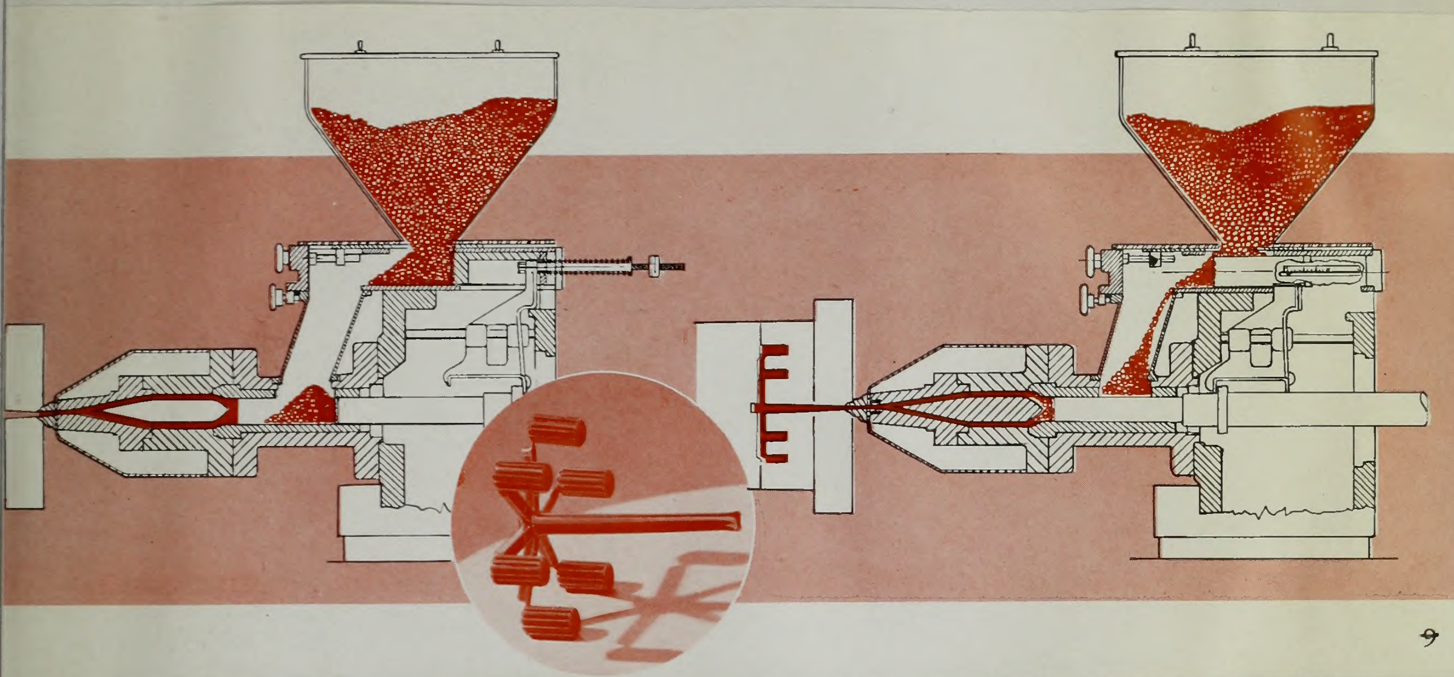

Fig. 10--Illustration of Principle of Injection Molding. (1)

machine. In 1941 these machines could conveniently handle only four ounces of material or supply a 26" mold cavity per plunger shot. (2) Larger machines are being developed.

The amount of material, therefore, determines the design of the orifice and different orifices are required when the product mold is changed. Owing to the high machine equipment costs in this method, mass production is necessary to compete with compression molding. For this reason these machines may complete ten cycles per minute allowing

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(1) Elmer E. Mills Corp., Injection Molded Plastics, Elmer E. Mills Corp. (Chicago, 1942)

(2) Simonds, H. R., Industrial Plastics, Pitman (N.Y. 1941) on page 95 limits the amount of material to less than 3 oz.

only about one second per cycle for the liquid material at 400° F. to fill the mold cavities. Pressure may be as high as 25,000 pounds per square inch. (1) For full time operation at a six second cycle a machine filling a five-cavity mold could produce 72,000 finished plastics parts in twenty-four hours. Productive capacity for small items is a leading merit.

5. Compression and Injection Molding Compared

Since the two outstanding molding methods are compression and injection each must have merits and disadvantages. In comparison therefore these points are noteworthy.

Injection molding is highly adapted to the manufacture of plastics with reinforcements or cores of laminated plastic or of metal. Thus finished metal products formerly cast to exact dimensions by die-casting, then nickel plated, may now be less accurately cast and used to strengthen a plastics-finished product which does not require further processing. At present some products made in this way are more expensive than the former but have the advantage of color variation and appearance and are more agreeable to touch. Furthermore artistic color schemes of related elements such as automobile upholstery and car door handles can be designed. In these applications the plastics thickness varies from 1/16" to 1/8".

Injection molds are less expensive than compression, there is less waste material, lower cleaning costs, also the raw materials range formerly limited to cellulose acetate is now broadening to include styrenes and acrylics which have a high raw material cost. Caseins are also being adapted.

(1) Simonds, H. R., Industrial Plastics, Pitman (N.Y. 1941) p. 97.

Among injection limitations are: (a) the size of product which can be molded: (b) present problems with regard to use of thermosetting plastics; (c) care required in mold design; (d) special preparation and mixing of powders.

Compression molding is adapted to: (a) large number of mold cavities; (b) large molded pieces; (c) all types of plastics molding materials. Disadvantages include: (a) excessive wear and possible damage to molds from the pressure needed to force the melted powder into shape; (b) slower process involving careful comparative unit cost analysis.

In general, with regard to other details, what is a disadvantage of one method may be an advantage of the other.

6. Transfer Molding

To obtain certain injection advantages for thermosetting plastics transfer molding was developed. This requires a preliminary heating of the phenolic so that it will flow into the mold, after which the final curing heat is applied. It thus goes one step further than the pre-warming of pills. Its advantages over compression are: (a) faster cavity filling; (b) lower curing heat; (c) casting strength and accuracy; (d) less waste material; (e) time saving; (f) lower finishing cost.

7. Plastics and Metal Combinations

The combination of plastics with metals has been indicated as a part of molding procedure. This is also directly applicable to strip plastics having an exposed metal surface for attachment to other elements of a structure of manufactured part; an example, stair railing. Metal cores may also be dipped in plastic in a manner similar to lacquer paint coating, and we are reminded that under proper conditions of chemical

processing phenolic elements may be used for lacquers. For some electrical parts the metals are covered with rubber insulation which is then encased in plastic by molding. The "spaghetti wire" of the radio industry is plastic covered directly and has the advantage of coloring to assist in following circuits after wiring installations have been completed. (1) Metals may also be the core of extruded plastics.

8. Molds

To this point, methods have covered the molding processes but little has been said about molds. These are almost always made of alloy steel of a composition determined by requirements of the final molding process and product, although lead molds were previously mentioned in connection with phenolic castings. (2) Mold design parallels the die design of the stamping or foundry business. Sand molds, of course, are useless. Molds are made by a machine process and the outer surface is hardened to withstand the heats and pressures so far described. Practical shop production of plastics demands practical mold design which requires sensible product design. These two designs sometimes proceed simultaneously to insure low cost plastics production. Items affecting mold design are: (a) ease of machining; (b) ease of removing the plastic; (c) access from raw liquid sources to mold cavities; (d) steel properties; (e) holes, projections, proportions of the product, and type of surface finish required; (f) molding material. In the molding process one authority states there are fifteen possible defects in the product arising from fifty-nine causes and having seventy-eight corrective measures.(3)

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(1) See page 35
(2) See page 26
(3) Boonton Molding Co., Plastics Reference,(Boonton, N.J., 1941) pp. 39-40

Where certain filler materials are used, molds must be able to hold a volume as much as eight times as large as the finished plastic object without losing an excessive amount from flashing at the mold joint.

The economy of molds depends considerably on volume of production. The essential factors are mold price, piece price, and monthly (sometimes weekly) production. An example follows:

TABLE NO. IX

EFFECT OF MOLD CAPACITY & PRODUCTION VOLUME ON COST

No. Cavities	Mold Cost	Piece Price	Monthly Prod.	Total Cost Mold and 100,000 pcs.
1	$ 200	5.0¢	10,000	$ 5200
2	375	4.0	16,000	4375
5	900	3.6	30,000	4500
10	1700	3.4	50,000	5100
30	5000	3.1	100,000	8100
50	7200	3.0	130,000	10200

Source: H. R. Simonds, Industrial Plastics, p. 110

This table, which resembles a bonus wage cost schedule, shows that for a 100,000 piece order the economical mold would have two cavities and produce 16,000 pieces per month. Several total cost factors have not been considered here.

9. Laminated Plastics

The elements of laminations have been noted previously. (1) More specifically, the phenolic or urea is treated with alcohol to form a varnish or syrup which impregnates the sheet of filler which passes through the varnish bath. The sheets are then partly dried and sections are cut and placed with fibres at right angles to each other, after which the stack

(1) See page 25

is heated and pressed into the final laminated sheet. Alcohol driven off in drying is reclaimed. Wood-veneer sheets are frequently used as filler and produce a grained finish for the plastic. Urea base materials, while in the varnish stage, retain the same coloring possibilities as in molding. Laminates may be colored on one side only, if desired. A laminate may also be provided with a color printed surface through the use of special ink for one of the filler sheets; or it may have metal or colored plastic inlays placed on the pile and forced in by the steel platten presses. Gloss or satin finish on the plastic is governed by the platten finish. Specific physical characteristics may be developed by the kind of filler and percentage of base content. Phenolics constitute the largest quantity of present laminates with ureas second, the latter, when in translucent form, tending to yellow slightly with age. Flour filler is recommended as an ingredient to reduce the cost of urea laminates.

An offshoot of the plywood laminate is laminated plywood, a development of the lumber industry. Whereas ordinary glued plywood separates under moisture and is subject to surface splits and mold, the new laminated plywood has the properties of the original phenolic laminate. It is impregnated with "varnish", the physical properties of which supersede the actual wood properties relegating the latter to a position of filler. The true laminate is better adapted to subsequent molding of thin sheets. Wood pre-treated with phenolic solutions acquires improved mechanical characteristics. It can be further compressed in finishing operations with less pressure than natural wood. This wood may also form the face-plies on uncompressed wood cores.

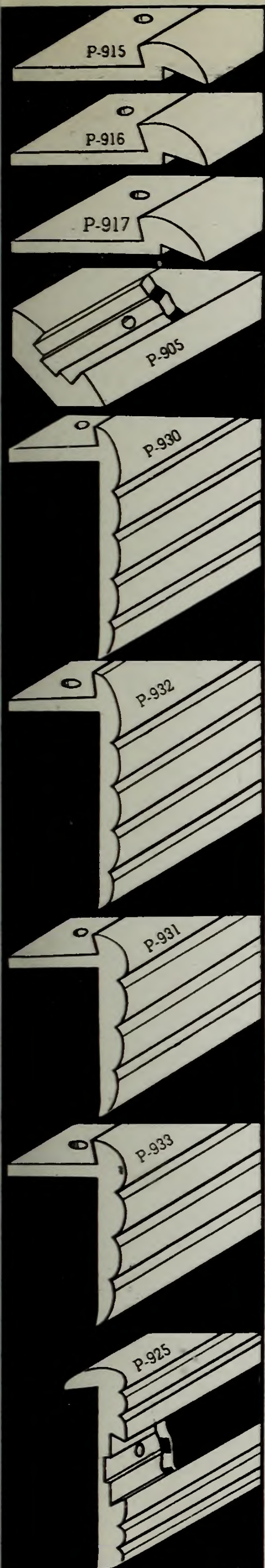
Fabric-filler laminates have been used industrially for gears and tubular bushings for several years and are now being extended to uses where the inherent properties of phenolic plastics are an advantage over previous materials.

10. Extruded Plastics

The extrusion process resembles the hamburg steak process. The powdered plastic material is heated and forced through a machine operation resembling injection molding except that the plastic product emerges from the heated end of the machine directly in final form and pre-shaped by the machine nozzle in sizes up to 3" diameter without going through a mold stage. Another extrusion version requires pre-preparation of a 75-pound raw dough batch which is placed in the extrusion machine to obtain a similar end product to the above. By another method the material is forced into 30 or 40 foot long molds where, upon heating, a product like an extrusion is formed.

The extrusion process is adaptable to most plastic materials, but some of the final products must then be ground and finished, such as Nitrates and Polystyrenes. Methyl Methacrylate and certain other acrylics do not need this latter treatment.

Extruded plastics will have the same competitive effect on chromium and nickel plated decorative trim as other plastics forms have in competition with older bright metal objects. One line of extruded architectural trim is illustrated on the following page. This manufacturer also produces aluminum and brass strip on a more extensive scale. Linoleum for color effect is used as an inserted strip in grooves formed in the plastic and also in the aluminum types.



MADUCO

TRADE MARK

Plastics MOULDING & TRIM

MACKLANBURG DUNCAN Co. QUALITY PRODUCTS

MADUCO WINS FIRST PRIZE

At the National Plastics Competition, New York City, with exhibits from hundreds of manufacturers, MADUCO Plastics Moulding was awarded highest honors in the architectural, furniture and interior decorations field.

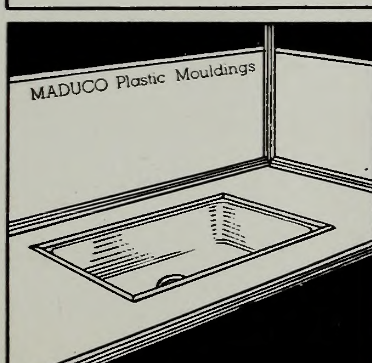
MADUCO Ivory Mouldings are beautiful in appearance, pleasingly suitable with any woodwork scheme. MADUCO is tough, and withstands, without blemish, severe shock from kitchen utelsils and other household equipment, resistant to chemicals and water; unaffected by exposure to extremes in temperature and humidity conditions and retains dimensional shape at all times without warpage or shrinkage. Color does not change, free from odor and light in weight. Maximum expansion 1/64" to 10-ft. length.

Numbers P-905, P-902, P-900, P-925 and P-901 take linoleum insert strips, available in red, blue, black or green, at 3c. list, per foot, over moulding prices shown below.

PRICES ■ LIST PRICES

Subject to change without notice.

SHAPE	504' & over per ft.	144' to 503' per ft.	12 ft. to 143 ft. per ft.	
No. P-900	$ .28	$ .30	$ .32	Hgt. 7/8"
No. P-901	.32	.34	.36	Hgt. 1"
No. P-902	.34	.36	.38	Hgt. 1 1/8"
No. P-905	.22	.24	.26	Width 7/8"
No. P-910	.22	.24	.26	1/2" under lip, for std. & med. linoleum
No. P-911	.23	.25	.27	1/2" under lip, for 1/8" materials
No. P-915	.25	.27	.29	1 1/8" overall, std. materials
No. P-916	.29	.31	.33	1 1/8" overall, for 1/8" materials
No. P-917	.25	.27	.29	1 1/8" overall, for med. ga. materials
No. P-920	.30	.32	.34	1" under lip
No. P-925	.34	.36	.38	1" under lip
No. P-930	.30	.32	.34	1 1/8" under lip, for std. & med. materials
No. P-931	.28	.30	.32	13/16" under lip, for std. & med. materials
No. P-932	.30	.32	.34	1 1/8" under lip, for 1/8" materials
No. P-933	.28	.30	.32	13/16" under lip, for 1/8" materials
No. P-935	.20	.22	.24	For std. & med. materials
No. P-936	.22	.24	.26	For 1/8" lino. and wall board

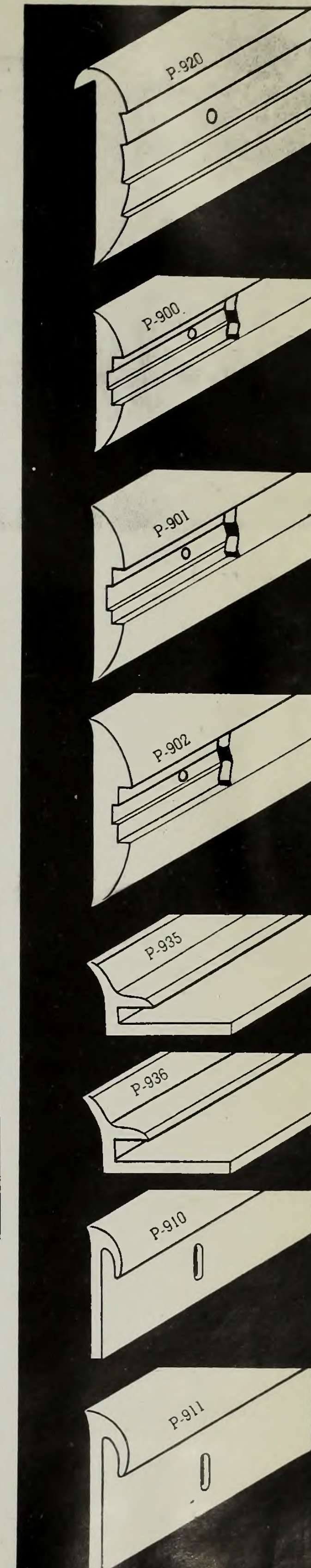


SO EASY TO APPLY . . .

MADUCO Mouldings are easily installed. Most of the shapes can be formed to almost any radius without heating or notching. When necessary to notch this can be done with scissors, snips or pocket knife.

BEAUTIFUL IVORY COLOR . . .

Maduco is furnished in a beautiful neutral Ivory color, which serves every purpose and allows dealer to meet all requirements with a minimum stock. Color schemes may be obtained by use of colored inserts. Samples furnished of any shape desired.



THE W. T. HIGHT CO., DISTRIBUTORS, 54 CANAL ST., BOSTON
TELEPHONES LAF. 1565-1566

Fig. 11

11. Summary

This completes the principal production methods at the present time but many incidental shop operations similar to those of the metal industries are to be found in a plastics factory. These include tumbling to remove excess fins, grinding, sawing to size, milling, drilling, buffing, stamping, marking, assembly, inspection, and even metal plating. Castings and stock extrusions can be machined and threaded on ordinary machine shop machines and tools just as soft metal products. Machine operations on products with abrasive fillers require special attention and harder tools.

Plastics of the softer cast types are suitable for the arts and crafts, both serious and hobby, and are being used as materials for sculpture and craft casting. Many beautiful transparent styrenes and acrylics have won prizes in their class at the annual "Modern Plastics" competitions.(1)

Assembly of plastics parts to other plastics, or to metals may be made by means of simple lid design, by allowing the flexible properties to snap the pieces together, by heat-expanding the plastic and allowing it to cool and grip the inserted part, by cementing, use of tapped inserts during molding, or by the use of various types of screws applied as in wood. Plastics have many features resembling other standard materials and some inherent characteristics which allow the use of many ordinary shop operations and equipment.

Marking plastics for trade mark or parts identification purposes may be accomplished by embossing or recessing the original mold, by plating or engraving, roll-leaf stamping (for packaging and advertising

(1) Modern Plastics, Vol. 18, No. 3, Nov. 1941, p. 60

novelties), electric iron writing, or inking. The latter method requires inks suitable to the given plastic's chemical properties. Instruction sheets issued with industrial laminates may become one of the layers in the process.

Another beautifying refinement intended to gain a market for plastics in competition with similar metal products is plating. By the application of a metallic bonding coat formed by patented chemical-reaction processes on the surface of the completed plastic the latter is made suitable for electro-plating in various metals. Plated designs can be created by masks similar to those used in photography. Metal surface inserts to form designs may also be attached to plastics by keyed grooves on the plastics surface to receive and hold the metal. Other ingenious methods are also practiced to provide metallic inlays for plastics. Decoration may be obtained by including metallic powders in the original plastics powder composition, and, since they retain their identity after molding, the product surface includes bright metal reflections or metallic ripples or other designs on the plastic.

With the above summary of manufacturing methods we come to the last of the three elements of manufacture which were set up to introduce the industry, namely, machines.

C. Plastics Machines

Our outline of materials and methods has given a general insight into equipment types for compression and injection molding and plastic pill making, and the various shop processes listed have implied the use of many incidental tools and small devices.

In a general way the small equipment resembles that of a foundry or machine shop and such instruments as micrometers, gauges, strength and physical property testing equipment are used in exactly the same way. Physical characteristics of the plant with reference to lighting, shop maintenance, mold storage, principles of industrial management, time studies, routing, scheduling, etc. resemble the management methods of a standard foundry, machine shop, or process industry depending on the phase of the plastics industry concerned.

Type of actual production machinery is, of course, the principal difference between the plastics molding plant and other similar plants. This machinery varies in type among the leading plastics producing countries. The two primary departments in the plant are the tool room, so-called, where the molds and dies are made,and the press room where actual production occurs. Although each part of a process is important, else it would not be employed, and although opinion varies as to the most important stage, considerable significance attaches also to the pilling operation since it controls the material economy of the plant.

The presses in which compression molding is done consist of hand, compressed air, or hydraulic types, the latter being the most common and most serviceable. Compression machines may be self-contained or dependent on various steam, air and water piping systems which supply several machines and involve much space and expense. Many space, mechanical, and shop-appearance advantages accrue to the self-contained units but these are expensive. Hydraulic press advantages include dependability, high and uniform pressures, and flexibility of use. Heating

medium for the powders may be steam, electricity or hot water. Contact thermostats or steam pressure reducing valves are used to control the press heat within 1° F. of the determined amount. Electricity controls the operating cycle, leaving only the pill insertion as a manual operation; while compressed air blows the finished product out of the mold. Mechanical classification of compression presses include upstroke, downstroke, angle, or combination, each of which has advantages and disadvantages. The type of press determines the principles on which the molds are designed.

The injection type of molding machine mentioned frequently in this work requires the following essentials: (a) uniform feed of raw materials; (b) uniform heat application; (c) positive mold closure; (d) high injection pressure; (e) fast liquid plastics flow through the machine; (f) correct timing and sequence control.

All these features of molding machines require exact mechanical detail and attention to the principles of industrial engineering affecting motion analysis, costs and handling.

Molds often may be considered permanent equipment to be used on repeat orders, or as stock items to be offered for use on standardized product orders. Extruded plastics of the type illustrated are also stock items in dealers' stock rooms. The molds include: (a) flash and split, for compression machines; (b) positive, for injection machines; (c) blowing.

Pilling machines are designed for job production use. By adjustment the rotary production type will go on making up to five thousand pills of given size per hour or until its supply drum is empty. The job

type requires an operator's attention since it produces only one pill per operation and is adapted to frequent change in pill size. Scales and inspection equipment are adjuncts of the pilling machine. Pilling rooms have temperatures up to 100° F. to preheat the pills in process for the molding machine. For multi-colored plastic products the pills are formed with the colors in specified positions so that the product will have its colors in the same relative position with relation to its mass.

SECTION IV - PLASTICS DESIGN

Having acquired some knowledge of the types and characteristics of important classes of plastics and near plastics, their chemical origins, physical forms, production methods, and practical advantages in use, it remains to be explained how these products are chosen for a specific purpose and how the final commercial forms and shapes are derived.

Many minds are behind these choices and these minds must adapt themselves to material characteristics. Mechanical, cost, artistic, novel, and psychological factors as well as good taste, conventionality, and personal fancy direct the minds.

Some products are designed by professional designers who re-style completely some obsolete type of equipment, or in a consulting capacity, help to devise the form of a new product, its color, material selection, proportions, attention to time saving and ease of utility features, and saleability, and who finally arrange for production.

Other products of more ordinary types having to do with mechanical operation of a machine, or simple consumer goods, may be designed by the distributing or assembling company. Often in these cases the plastics molding company must recommend or advise on the correct material and assist in many ways during production.

A third design approach is through a company's own design and research departments to devise improved products to be made within the plant.

An almost unique feature is the production by molding companies of stock moldings catalogued and available on short notice to equipment designers and assembly companies.

Industrial product design requires astuteness and knowledge of the type of customers to be sold and the designer's success depends partly on how well his design "takes", as reflected in company sales. While responsible for new ideas he is faced with need for keeping within the general trend of the times, leading the field gradually into new trends, yet selling his ideas to his own organization, the executives of which frequently are conservative by nature and sales conscious by necessity. The staff designer, while trying to help the executive to more sales, is often defeated in the paper stages by executive objections, assuming that his technical and production knowledge is adequate to assure mechanical feasibility. Professional designers fare better because of name and fees. Both types must understand materials and perceive form and use for products.

Many applications of materials through the ages have resulted from designers' ideas supported by their mechanical and materials knowledge, and sometimes by their faith and ability to induce others to try the new application. So with plastics, new uses will be conceived by designers and new materials will appear because of their requirements, as soon as the chemists perfect them. Such freedom of choice is more adapted to architecture than to merchandising since the latter is dictated by commercial experience, and new merchandising gadgets and containers must be approved by advertising and distribution specialists in addition to the creative and technical minds.

Early design in plastics failed to emphasize plastics due to: (a) an effort to conceal the plastic through lack of knowledge of the material's value; (b) poor conception of color possibilities; (c) poor

design ability; (d) use of plastics combinations to imitate other materials.[1] The latter effect so cheapened the field that it was only with difficulty that outstanding consulting designers were able to interest discriminating distributors in the use of plastics for containers. (2) This point, however, does not agree with the principle of mass production by which it is hoped to make more goods available to more people at lower costs. The more pieces that are produced from a given design the more commonplace they will become, but whether this will necessarily imply cheapness in taste, besides cheapness in price, is problematical.

Plastics objects of the convenience variety became sufficiently important in 1928 to require attention to design but the meritorious results of industrial designers were not achieved for several years. Product design simplicity resulting from reduced cost policies in the 1929 depression has persisted to the advantage of design in general. Mold design has improved. Color controls have developed. Clean and dirt-free molding has become mandatory. The result: faultless, delicately colored, curved, massive motif in plastics of individual distinction. This has marked the passing of the plastics-as-a-substitute period during ordinary times.

Whereas the drab phenolics failed to inspire marked effort at design, the advent of ureas with light ivory effects stimulated design and after the establishment of ureas in small electrical parts for home consumption an unsuccessful period of plastics tableware arrived to be

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(1) Simonds, H. K., Industrial Plastics, Pitman, (N.Y. 1941) p. 270
(2) Ibid, p. 270

followed between 1930 and 1935 by small personal items and brightly colored parts, also larger radio housings.

Design progress has combined the development of a period school with the practical considerations of shop production improvements, the common sense of utility refinements and the dictates of commercial necessity. Thus, between the years just noted edges and lines were superseded by curves and blending, elements and projections conformed to economical mold requirements; ease of handling, principles of motion economy and elimination of unnecessary features were included in the design in order to assist the consumer in his use of the product, and smart styling, new plastic material combinations, compactness and price economies were devised to aid the distributors.

Material characteristics and molding progress were probably most important in making smart simplified products possible since the larger plastic devices today, such as machine housings, contain fewer parts. Actual design features are related to the product's use and molding technique. Where the plastics will be emphasized by light, as in lighting fixtures, bowl decorations can be created by varying the plastics thickness in molding. Light transmission through the bowl will then disclose the decorations. Colored molding powders used for the thickened portions further enhance fixture appearance under lighted conditions.

Embossed detail on the product's surface is more practical than recessed detail, from the die maker's point of view. Depth of embossing is a nice matter of design judgment. Material economy and molding procedures also dictate the thickness of product elements and the

best locations for projecting ornament. Cleaning and maintenance of the product by the consumer dictate the need for curves and adequate spaces between embossed lines. The form of the design with reference to corners, strength, inserts and thicknesses requires the designer to have good mechanical ability.

Design procedure consists of rough sketches, colored product drawing, dimensional drawing, mold drawing, estimate drawing, and possible plaster casts for study and illustration, before the product can be approved for production.

Color for plastics products in the design stage calls for an understanding of color theory and principles, worthy of an artist. Among the factors pertaining to color are proper application of contrast and harmony, effect of color on optical illusion and apparent size of the product, psychological effects of color connected with the ultimate use of the product, color values, relative costs of colored dies and pigments for molding, visibility of color combinations at various distances.

Color association is another factor which creates a problem in economical production of many products even outside the plastics field. Companies are identified with products and products are identified with color combinations on the containers. This fact is of great importance in the advertising, packaging and merchandising fields and when applied to plastics may decide the choice of colors for plastics advertising novelties, plastics containers or closures for distribution, or for a plastics product in its own right. Combinations of several colors, particularly in a recognized or established pattern,will usually affect the cost of the product and influence its molding procedure. Color patterns

of this type may have more appeal as the product or symbol of a standard brand than as a source of color appeal for individual sales. When many identically colored pieces are produced the color appeal is lost. Color choices based on usual preferences among consumers are needed to maintain color appeal. Therefore, the plastics product must be designed and colored according to one of the foregoing considerations for ordinary commercial purposes, particularly for consumer goods. The absence of color variety hindered the early phenolic plastics, as we have seen. Light pastels for plastics for consumer use are said to produce the best sales appeal. (1)

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(1) Simonds, H. K., Industrial Plastics, Pitman (N.Y. 1941) p. 315

SECTION V - PLASTICS IN ARCHITECTURE AND CONSTRUCTION

The architectural application of plastics involves judgment and knowledge on the part of the designer as to: (a) the practical properties of materials; (b) the relative importance of materials costs; (c) proper use of the plastic as an element of a building or as part of a fixture to be installed in a building. Architecture may under some conditions include the design of fixtures for specific architectural applications, also the choice, specification, or even the design of furniture and furnishings for a given building or room where a definite effect is to be obtained.

Frequently, selection of furnishings and color are the functions of interior decorating; furniture creation, the work of artistic designers; and the development of shape and material trends in semi-architectural applications, the work of industrial designers whose duties lap over into commercial packaging and product design. The development of industrial process plants is the combined work of architects and industrial engineers. Residence design is most frequently done by architects or by builders.

In a broad summary of plastics uses in architecture it is interesting to note examples in some of the foregoing branches of endeavor and in so doing a separate section of this thesis will be given over to the packaging and display uses for plastics. (1) In this section on architecture, therefore, references will be made under the headings: (a) residences; (b) commercial and industrial buildings; (c) furniture and furnishings; (d) electrical fixtures.

(1) See pages 108-120

A. Activity in Residential Construction

Before taking up plastics in home construction it would be well to note present trends in residential construction in order to observe what opportunities are available for plastics materials.

Recent activity in this type of construction as compared with construction at five-year intervals is indicated in the following table which does not include defense housing. (1)

These figures show considerable variation in number of units built during the different years and show no consistent trend. There is some relation between single residence construction in 1925 and in 1940 and 1941, implying a possible normal demand for this class of construction in good business years, particularly if there has been a long period of business inactivity. The 1942 total estimate given in the table may be low when the final figures are tabulated since the early estimate for 1941 was 519,000 houses whereas the actual number turned out to be 650,000. The bulk of construction continues in urban areas but the percentage of increase in rural construction is greater than in urban construction and the per cent of total residential construction represented by rural is slightly more than formerly. The latter trend is shown by the figures in Table No. XI on page 68. (2)

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(1) See Table No. X, page 67
(2) See Table No. XI, page 68

TABLE NO. X

TOTAL DWELLING UNITS BUILT IN THE UNITED STATES
(Not Including Farmhouses)

Year	One Family		Two Family		Multi-Family		Total all Types	Urban	Rural (Non-Farm)	Total (as before)
	No.	% of Tot.	No.	% of Tot.	No.	% of Tot.				
1920	202,000	81.8	24,000	9.7	21,000	8.5	247,000	196,000	51,000	247,000
1925	572,000	61.0	157,000	16.8	208,000	22.2	937,000	752,000	185,000	937,000
1930	185,000	64.7	28,000	9.8	73,000	25.5	286,000	224,000	62,000	286,000
1935	110,000	76.4	6,000	4.2	28,000	19.4	144,000	106,000	38,000	144,000
1940	436,000	80.0	32,700	6.0	76,300	14.0	545,000	398,000	147,000	545,000
1941	547,000	83.0	33,000	5.0	70,000	11.0	650,000	472,000	178,000	650,000

1942 Total estimated units to be constructed: 500,000

Source: American Builder: Vol. 63, No. 1, Jan. 1941, pp. 31-33
Vol. 64, No. 1, Jan. 1942, pp. 36-40

TABLE NO. XI

RESIDENTIAL CONSTRUCTION AS COMPARED WITH PREVIOUS YEAR

	1940	1941
Towns: Population 25,000 to 50,000:	+ 38%	+ 9%
Towns: Population 10,000 to 25,000:	+ 30%	+ 21%
Rural Non-Farm Construction:	+ 20.8%	+ 25%
Large Cities:	- 3%	+ 0.06%

Source: American Builder, Vol. 63, No. 1, Jan. 1941, pp. 31-33

Referring to the table of total dwelling units on page 66, it is seen that the percentage of two-family houses has not returned to the place it held in 1925 and there had been an even more constant decline in apartment buildings. Today emphasis is on small single homes. This is indicated by the Federal Housing Administration mortgage values, the average of which in 1935 was $4824; in 1940, $4417; and in 1941 ranged from $2800 to $5500. (1) Allowance should be made for possible changes in policies of the administration regarding types of homes to be mortgaged and values of these homes since such a change will affect, to some extent, the apparent trend in size of homes.

Value of Construction other than Residential

Recent values of construction other than residential types are shown by the following figures. (2) It is difficult to show a definite relation between the value of housing construction and of other types since the factors contributing to each are different and the construction cycles are different. The value of home construction in 1940 was nearly 50% more than the total of all other types, but in 1941 the total values were about equal and the forecasts for 1942 show a similar degree of equality.

(1) Prospects for 1941 (also Prospects for 1942), American Builder, Vols. 63 and 64, Nos. 1, Jan. 1941 and 1942, pp. 31-33 and 36-40

(2) See Table No. XII, page 69

TABLE NO. XII

ESTIMATED BUILDING CONSTRUCTION VALUES
OTHER THAN RESIDENTIAL CONSTRUCTION
(Millions of Dollars)

Class of Construction	1940	1941	1942 (Est.)
Manufacturing Buildings	442	1175	1175
Commercial "	318	490	330
Educational "	147	145	90
Hospitals and Institutions	94	100	75
Public Buildings	80	85	15
Religious "	46	55	15
Recreational "	63	80	50
Miscellaneous"	104	250	110
Total:	1294	2380	1860
Residential (Non-Farm)	1850	----	1491

Source: American Builder: Vol. 64, No. 1, Jan. 1942, pp. 36-40

While the foregoing figures do not cover defense housing, the expanding need at present is, nevertheless, centered largely, but not wholly, on suitable homes for war industry employees.

B. Renovation Services and Construction of Small Homes

1. Prefabricated Housing

The most inexpensive housing in this present emergency is prefabricated principally from plywoods, composition materials such as Masonite, or from inexpensive lumber, and the interior furnishings and equipment are quite simple, serving a utility purpose. Comparatively little attention seems to be given to decoration or novelty in this class of housing although even with such small amenities as are provided, the quality of building is usually far above that of equally priced construction in former years, due to modern materials and design features.

2. <u>Housing from Builders' Plans</u>

Next in order are the privately or government-financed tract developments where the homes are built from builders' plans offering two or three types of house with variations of room arrangement. These give more opportunity for builders' ingenuity, experience, or taste with reference to exterior and interior style, decoration, and use of materials. The cost of these buildings is generally above that of the prefabricated variety.

3. <u>Housing from Architects' Designs</u>

Other small homes are designed by architects for construction by builders. These may often provide efficient arrangement, appointments chosen with professional skill, and materials and design features so specified as to incorporate the best for the buyer's money. The owner profits from the architect's ability and training. Homes of this type are more likely to be individualized and different from neighboring homes. With care in design their costs can be kept on a level with the builder's project type. For a higher price relatively more elaborately planned and individual appearing residences can be developed.

In all these classes of construction costs vary with the section of the country owing to differences in prevailing trades wages, materials costs, salary range of buyers, and the equipment and architectural style demanded by the climate.

4. <u>Renovations in Existing Buildings</u>

In addition to the recent growth in new residential construction there is an increase in alteration and renovation work both of homes and of commercial properties. In the case of home modernizing there are two

interested individuals: (a) the owner; (b) the builder. We assume in this case that architects are not employed. Neither of the principals may be thoroughly familiar with many possibilities of a renovating project, least likely the owner or his wife. For these people there are expert services offered by manufacturers of building materials and equipment through specialized home service departments which will prepare plans, specifications, suggestions and color schemes for kitchens, bathrooms, general redecorating, exterior painting, and even entire houses. Designs are made on a direct mail basis from sketches submitted by the prospects and in some cases scale templates of manufacturer's equipment are lent to the home owner so that he may first plan new equipment or furnishings locations to suit his taste before ordering. (1)

Among the leading companies providing such services are: General Electric, Kitchen Maid, Youngstown Sheet and Tube, Crane, Upson Board, Pittsburg Plate Glass, Armstrong Cork, and Sherwin-Williams. These companies, known for specific building equipment, do not limit their recommendations to their own products. For a concern like General Electric, however, there is great opportunity to introduce plastics for kitchen or bathroom trim or for general lighting use owing to the manufacture by the company of Textolite laminates and Micarta plastics for integral parts of other products of the company, or for sale as sheets for further fabrication.

Bakelite, Tenite, or laminated stock handles, knobs, and flat surfaces of other appropriate plastics materials might well be incorporated as standard equipment on the products of various manufacturers

(1) Campbell, Janet, Planning Services Help Builders, American Builder, Vol. 63, No. 8, Aug. 1941, p. 68

owing to the possibility of obtaining such parts on contract in a similar manner to hardware or other small parts for assembly line production of the manufacturer's product.

The advantages of the services just outlined are: (a) to further publicize quality products and reputable manufacturers; (b) to develop contacts between contractors and prospects through company referals.

The outlets for plastics products in this phase of architecture are: (a) through contracts with manufacturers of equipment to provide plastics parts; (b) through establishment of customer services in connection with such plastics products as floor covering or laminated finishes. Such methods are in use to some extent among plywood manufacturers.

C. Opportunities for Plastics in Construction as Result of War Materials Shortages

Construction of the new housing, particularly that required for war production centers demands speed and economy, and because of favorable priorities on the standard housing materials, other than metals, this class of construction, next to actual cantonment needs, is well provided with wood, cement, roofing, and general finishing materials. The principal economies in housing apply to metals which can be used in direct war production. Metals in construction are used in reinforcing, flashing, piping, wiring, hardware, heating andventilating equipment, and kitchen and plumbing fixtures, and a miscellany of small items. Thus, to replace metals, plastics must be extremely cheap and must have the required mechanical qualities to substitute for these materials.

Figures compiled by the Federal Housing Administration in 1940 show the following interesting analysis of critical metals used per 1000 single-family homes financed during that year by the agency:

TABLE NO. XIII

AMOUNT OF METAL PER 1000 FHA SINGLE-FAMILY HOMES BUILT IN 1940

Metal	Purpose: Structure lbs.	Heating lbs.	Plumbing lbs.	Electrical Wiring-lbs	Total lbs.	Rough Ave. Typical Home
Iron & Steel	1,668,621	1,181,857	1,600,065	84,575	4,535,118	4500 lbs.
Copper	48,389	12,221	94,940	27,746	184,296	184 "
Zinc	37,954	18,102	32,756	5,729	94,541	94 "
Lead	173	2,842	84,863	-----	87,878	88 "
Tin	258	927	991	510	2,686	2.7"
Aluminum	284	563	253	-----	1,100	1.1"
Monel	---	---	756	-----	756	0.75"
Nickel	18	7	258	-----	258	0.28"
Total Metals	1,755,697	1,216,519	1,814,882	118,560	4,906,633	4870.83 lbs.

Source: Amounts of Critical Material for Home Building are Small, American Builder, Vol. 63, No. 10, Oct. 1941, p. 61

It is estimated that weights of iron and steel, copper, and zinc will be reduced in 1942 construction by one-third, two-thirds, and one-half respectively. Weights of other metals are relatively small per dwelling but some economies will doubtless be practiced here as well.

As has been indicated elsewhere, plastics at present range higher in price per comparable unit of measure than the more common materials.(1) They also face the following disadvantages owing to their comparative newness: (a) insufficient evidence of structural value from standardized tests or past experience; (b) limitations imposed by municipal construction codes for structural members; (c) lack of precedent among architects and

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(1) See Table No. VIII, page 12

builders; (d) personal preference; (e) tendency to apply them extensively only in more expensive types of residential construction. Since 1941, however, their field has broadened through: (a) use as standard parts of architectural equipment by manufacturers, as in lighting fixtures, thus creeping into building construction through the equipment field; (b) through reports of their use in specific instances; (c) through actual evidence of special qualities for practical purposes; and (d) through necessity for replacing more common materials.

It is apparent, therefore, that where metal reductions are not made by complete elimination of specific features of design from the house plans, plastics should have an opportunity to replace such materials by virtue of being the only practical substitutes available. Price differentials in such a case are not as important as they would be were competing materials freely available, and plastics thus have an unexpected occasion to prove their merits and to gain a place in the construction business. To assure this advantage plastics prices must not rise with corresponding alacrity as general construction costs rise during present conditions. It is probably true, also, that even where plastics costs are somewhat higher than the costs of more common materials used for the same purpose, the per cent of total construction cost represented by cost of plastics elements would not be as high when the general level of construction costs is high, and on such a basis the opportunities for plastics have a second advantage. The condition of rising general construction costs has been present for the past two years and in some types of construction there has been a more or less corresponding increase in the application of plastics, and a definite increase in professional discussion of the merits of plastics.

Between June and November 1940 there was a ten per cent increase in the cost of medium size home construction in the St. Louis area and the following analysis of costs of identical six-room frame houses built in these months, as made by a local builder on the basis of careful cost accounting, covers the items causing the increase.

TABLE NO. XIV

INCREASE IN COST OF RESIDENTIAL CONSTRUCTION, ST. LOUIS: 1940

Total Cost (November 1940):	$6611.
Total Cost (June 1940):	6004.
Amount of Increase:	$ 607.
Per Cent of Increase:	10.
Dollar Increase by Items	
Unfinished Lumber:	$ 122.
Finished Lumber:	154.
Millwork:	80.
Labor (Plumbing):	30.
Overhead (Sub-Contract):	33.
Overhead (Gen. Contract):	24.
Total Increase:	$ 607.

Source: Prospects for 1941, American Builder, Vol. 63, No. 1, Jan. 1941, p. 68

It can be seen from these figures that, in the case in point at least, plastics for ornamental trim would be on a more nearly equal footing with finished lumber on a cost comparison basis than before the rise in costs occurred. Furthermore, with the added cost of millwork, direct labor, and various forms of overhead, the per cent of total cost represented by expensive plastics would be somewhat reduced, thus admitting them to consideration when selecting materials for specific purposes.

The additional demand resulting from the choice of plastics would eventually cause a volume price reduction and further insure plastics a place among building materials. There is, therefore, an opportunity for temporarily more expensive products to gain markets when the general level of competing product prices is high, or when the supply of competing products is limited.

D. Residences

Although residential construction comprises a large part of the total construction in the country it is so necessary to keep costs within reach of the people for whom the homes are constructed that materials are chosen for low cost, durability and conventionality in this class of construction more than in any other type. Since we have found that plastics at the present time, or recently passed time, are rather more expensive than other possible materials we should not expect immediate large applications of synthetics or new creations in any but the most expensive homes, and for the time being, therefore, plastics should only appear in small pieces of furniture, utensils, containers, and clothing ornaments. This is not quite true, however, since within the past two years special applications have been developed which introduce the new products to actual small residential uses. More extensive use occurs in larger commercial buildings where there is some form of profit motive in adding flare and novelty to the design and appointments of the structure. When these examples succeed in reducing production costs sufficiently the smaller buildings will be better able to use plastics extensively.

E. Plastics and Glass

1. Glass

Among the coming uses for plastics in small homes is the acetate film or sheet window which is already in direct competition with window glass. Other transparent plastics possibilities beyond this small beginning have caused considerable activity in the glass industry to refine its products and to develop new uses for glass to ward off the threat of future plastics domination. The great reduction in glass demand caused by the shut down of the automobile industry has further emphasized the need for new glass outlets in volume. During 1941 the automobile situation caused a reduction of 65% in the volume of glass formerly required for automobiles.

Today glass is expected to fill in for aluminum, brass, bronze, steel, iron, cork, synthetic plastics, asbestos, rayon and rubber. The four principal forms of glass are: (a) blocks and flat sheets; (b) containers; (c) blown shapes; (d) fibres. Glass is now used in place of stainless steel or enameled steels and rubber in restaurant, ice cream and refrigerating equipment; for table tops; to replace plastic furniture handles; also for housings, lenses, flooring, roofing, shingles, springs, pipes and pumps, household electrical devices, accoustical and heat-insulating materials and fireproof draperies. Many of these glass items are in direct competition with plastics.

Although glass has been on the market for many years in its ordinary forms, it is now required to add to its field and in so doing it may develop an even more formidable place in the field of specialized use materials, thus hindering plastics in their development. It must be

remembered, however, that there is a wider opportunity for new plastics due to their chemical nature, whereas glass most likely must depend on refinements and developments of its present medium.

2. Plastics Window Material

As the acetates and acrylics move on to conquer a place in the building sun for transparent safety purposes it is found that the possibility of air raids has given impetus recently to the development of shatter-proof window plastics to replace glass, and the number of small homes and large which could use such windows are legion. Considerable personal injury from raids is caused by flying glass. Shatter-proof glass (which was always composed of glass layers bound together by cellulose acetate plastic) and the former wire-reinforced safety glass, so often required by fire laws, is relatively expensive for residential use and has not been extensively installed. Shatter-proof Vuelite (Cellulose Acetate) panes up to a 17" x 20" size, and consisting of two sheets of plastic approximately 1/8" thick pressed together with standard wire mesh screening between, to form a single finished pane little over 1/4" thick are now used in military camp construction and are available for home use.

These panes are resistant to damage from concussion and vacuum and are over sixteen times as resistant to falling bodies as ordinary safety glass. Visibility through the pane is less than in the case of glass but this is partly due to the reinforcing screen. Owing to its thermoplastic qualities this pane can be formed into curved shapes more easily than glass. It is applicable to either wood or steel sash and costs approximately one-half as much as safety glass, thus being little

more expensive than ordinary glass. There is considerable possibility of its use in fire door installation and for other safety purposes in peace times, and panes even without wire mesh may become superior to ordinary glass and will be safer in home construction. (1)

Other more temporary forms of window plastics include laminated cloth and cellulose, and wire dipped in cellulose. The cloth variety known as "Celoglass" is recommended for temporary window and door construction in defense housing by a California designer, Joseph Allen Stein, who also suggests plastic pipe and glass faucets as metals substitutes. (2) The substitute and safety value of many of his design features is emphasized by this architect who indicates that most of these "temporary" materials can be replaced after the war by more durable elements. By that time, however, they may not be regarded as temporary owing to more serious application within the next year or so in residential construction. Housing units in which these features appear together with certain novel structural innovations are intended to cost not more than $2000 each when built in quantities of 500 or more. At this price, however, such buildings could only be used in a semi-tropical climate since, necessarily, more substantial construction and equipment required for colder climates would raise the total cost appreciably.

3. Plastics Structural Blocks

Another plastics use in competition with glass occurs in the new "Lumitile" which serves a purpose similar to glass building blocks. For several years glass blocks, clear or colored, and in varying designs

(1) Wired Window Protection, Modern Plastics, Vol. 19, No. 11, July 1942, p. 52

(2) Stein, J. A., California Arts and Architecture, Vol. 59, No. 6, July 1942, p. 5

and degrees of transparency have been used to admit light in place of windows while assuming structural responsibilities ordinarily borne by brick and concrete. They are now being used increasingly as external surfaces for large structures, for interior light distribution, and to provide variation in architectural effect where strength is less important. In 1940, however, translucent and colored Lustron blocks of styrene were developed and are now available in competition with glass. They have the advantage of light weight, coloring possibilities, durability and water resistance plus the somewhat transitory value of ultra-modernness. They are, on the other hand, more expensive than glass and are too weak for use as bearing members in construction. Their present field, therefore, is in café, commercial and theater lobbies, and living rooms where illuminated decorative effects are desired. (1)

4. Plastics Numerals

A further instance of plastics in competition with glass in a very insignificant way is seen in the use of plastics address numerals for gates, letter-boxes, and entrance doors. These are frequently made of phenolics or other weather resisting plastics and those having properly shaped methacrylic or glass inserts or buttons become luminous from external light rays at night and are, therefore, useful at all times.

5. Plastics to Compliment Stained Glass

There may be possibilities for plastics in the stained glass business if pressureless casting of transparent and translucent phenolics or colored acrylics can find a place, with the passage of time. This

(1) Plastic Tiles Give Promise for Decorative Walls, Scientific American, Vol. 164, No. 7, Feb. 1941, pp. 92-93

field is highly refined and it will require patience and selling to convince the artists, designers and craftsmen of the value of plastics to replace the glass which is so difficult to produce; yet it is possible to control plastics and to develop desired results almost at will. No instances appear to be recorded showing efforts in this direction but if suitably clear colors and reasonable costs for very small amounts of job-order plastics can be developed these materials would have several advantages over glass in safety, durability, and light weight. The possibilities of fusing or cementing adjoining pieces of a window design without the use of lead channels is another consideration although the finished work would probably develop an effect and individuality of its own owing to the lack of the leadwork.

F. Cotton Fabric Plastics

Leaving the glasslike plastics, there is an entirely different use for a variety of synthetic resin-bonded semi-plastics in the prefabricated housing line. At present sparingly used in trial applications is a novel use of cotton fabric which is applied directly to the exposed surfaces of plywood wall and ceiling panels for this type of housing construction by means of waterproof synthetic resin adhesive. (1) Advantages claimed for the finished product are: (a) the formation by the fabric of a better draft and vapor barrier than that formed by wood; (b) formation of a superior base for wall paper or painted decoration. In the case of a five-room sample display house, prefabricated in wood, ordered by the United States Department of Agriculture, and having outside dimensions of 32 ft. x 24 ft., 4500 square feet of cotton textile

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(1) Cotton Walls, Architectural Forum, Vol. 74, No. 10, April 1941, p. 70.

were used in covering the panels. The company which provided the housing construction had on order for the month of February, 1941, 1.25 million square feet of cotton fabric for this purpose. It should be noted that although resin-bonded fabric would be a better windbreak than ordinary wood, the same effect could be obtained from resin impregnated plywood. (1)

G. Plastics in Remodelling

Although the foregoing references only indicate a small number of uses for plastics in small house construction, there are numerous growing opportunities for plastics and a hypothetical example can easily be built up from an imaginary renovating job to show the extent to which these materials could be used independently or in conjunction with other older materials to transform an obsolete interior into a modernized one.

In renovating interiors considerable taste is required in order to keep the changes within the limits of architectural style and fitness imposed by the portions of the interior which cannot be changed for structural, financial or other reasons. Poor choice might lead to a case of modernistic monstrosity where only a modernization of an outmoded style was intended. Thus a period interior might be ruined by a promiscuous use of plastics. Appropriateness of detail must be observed. For ordinary interiors more latitude is allowable. With these limitations in mind in addition to structural and mechanical considerations much can be accomplished.

In many old time brownstone front or mansard roof structures or colonial farm houses there are cozy corners sometimes located in

(1) Cotton Walls, Architectural Forum, Vol. 74, No. 10, April 1941, p. 70

semi-circular construction projecting from one corner of the house, or on the first floor under the bend in a stairway, or perhaps a small room is set apart. Many such settings have in the past had heavy dark wood furniture, highly varnished light finish or dark finish columns, wood trim, mantel piece, and fireplace trim, or other older period trim; or possibly the entire effect has been dark mahogany, or in rare instances even ornately carved teakwood. Other nicknacks and potteryware on whatnots, old mechanical clocks, and such arrays of typical period finishes and furnishings have had to be replaced during a modernizing program.

By a careful choice of decorating materials, structural elements, furniture, trim, modern ornamental nicknacks and electrical fixtures, such a corner could conceivably be done in plastics without use of other redesigned old line materials such as glass, wallpaper or wood trim. Thus, carved wainscoting gives way to laminated phenolic plywood in natural finish with complimentary or contrasting colored urea phenolic baseboard and a bright or conservative chair rail at a practical height. Wall joints and corners would be filled with extruded plastic beading between panels. More laminates of cloth base could replace mantel pieces and serve as facing trim for fireplaces. Transparent pastel shaded acrylics could serve as draft breakers to replace an old turned wood balustrade while allowing visibility from the stairway. Vinyl or other rubbery content floor tile could add to apredetermined effect by its color, and waterproof plastic treated curtains could be installed in a chance window. More extrusions would ornament the outer edges of the shelves of an open bookshelf tier to replace an old bookcase. Furniture of modern open construction with woven plastic reed seats or laminated

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table top would fit into such a nook, and a plastic bridge lamp and urea wall bracket lighting fixtures would finish off the effect except for a few methacrylate or styrene transparent figures on the mantel. The need for careful choice is obvious and the personal preferences of the tenants of such a plastic paradise, together with cost considerations, would determine how many elements were to be of plastics and how many of other materials. Similar instances of actual uses for the variety of plastics will be brought out in subsequent sections. (1)

H. Commercial and Industrial Buildings

There is a greater use of plastics in the case of commercial buildings and interiors than in any of the other types of construction, but even here the uses are somewhat limited at present to decorative and ornamental elements where the sales appeal is high or where definitely practical reasons dictate plastics for small uses.

1. Restaurant

An example of plastics in an ultra-modern restaurant in Jackson, Mississippi, occurs in the use of Formica, a cloth base phenolic laminate, for the table tops and counter tops, also through the use of wood fibre "Insulite" blocks for walls and ceilings. Imitation walnut finish Celotex was used for certain other wall surfaces. These latter materials, in addition to being modern and semi-plastic, are also soundproof. The early tendency to use plastics as substitutes is illustrated by the selection of a pattern to imitate walnut. Lighting in this installation is provided by a combination of fluorescent and neon tubes. (2)

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(1) See page 92
(2) Color, Light & Modern Equipment, Attract Restaurant Patrons, American Builder, Vol. 63, No. 5, May 1941, pp. 74-75

table top would fit into such a nook, and a plastic bridge lamp and three wall bracket lighting fixtures would finish off the effect except for a few methacrylate or styrene transparent figures on the mantel. The need for careful choice is obvious and the personal preferences of the tenants of such a plastic paradise, together with cost considerations, would determine how many elements were to be of plastics and how many of other materials. Similar instances of actual uses for the variety of plastics will be brought out in subsequent sections. (1)

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(1) See page 92
(2) <u>Color, Light & Modern Equipment, [illegible] Restaurant Pattern</u>, American Builder, Vol. 63, No. 5, May 1941, pp. 74-75

2. Chain Stores

Another example of the use of Formica occurs in the lining surface of display niches and wall recesses in several units of a retail bakery store chain in New York City. White Formica is used for cleanliness and to reflect display lighting. Five-ply walnut finish plywood is used for the general interior finish of the store and the counters. Bronze snap-on moldings are used for ornamental finish between joints of the woodwork. This metal is an architect's choice but as with all metal moldings, the colors are limited to silvers, coppers, aluminum, steel gray, or bronze. Plastic extrusions could be used in these instances as standard stock strip in a variety of colors. (1)

3. Hotel

The new Friederika Hotel in Little Rock, Arkansas, has applied laminated plastics for the tops of birch tables in all guest rooms. The specific advantage in this case was to prevent damage from cigarettes and alcohol. (2) Venetian blinds at this hotel are metal. Plastics blinds, however, are now entering the building equipment field.

I. Plastics and Wood

1. Savings in Finishing Cost

In a description of the wall treatment in the waiting room of the deluxe filling station of the Maxwell Petroleum Corporation at Tacoma, Washington, the following occurs: (3)

> "The woodwork (knotty pine) is painted to give a blond finish. One coat of interior flat white was applied and wiped off. This was followed by two coats of Schorn's Nudene, a transparent finish. A coat of paste was ~~was~~ applied and rubbed down giving the walls a beautiful, faintly white finish."

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(1) One Store Job That Led To 100 More, American Builder, Vol. 63, No. 1, Jan. 1941, pp. 53-55

(2) Friederika Hotel, Little Rock, Ark., Views, Plans; Architectural Forum, Vol. 76, No. 6, June 1942, pp. 378-382

(3) Smart Styling in Gas Stations, American Builder, Vol. 63, No. 5,

In this example of the work involved in preparing natural surface woods without final paint coats there are four applications of semi-finishing and finishing materials in addition to the removal of part of the first coat and the probable roughening of the second and third coats by sanding before applying the final polishing wax. Much of this work and the variety of paints and finishes could have been eliminated through the use of one of the Bakelites or even Vitrolite or other colored architectural glass. Incidentally, in this filling station, Celotex sound insulating was used on the ceiling.

Although such a suggestion for using plastic panels to replace wood might produce certain labor saving, and even were the plastics cost less than that of wood plus labor and finishing materials, there might still be an objection to the final effect of the plastics on the entire architectural scheme, as compared with knotty pine. The esthetic effect intended by the architect might be destroyed.

2. Wood Pulp Plastics

Wood pulp plastics, a powder-molded thermoplastic product, known as Tritex (1), might be used to a limited extent where a wooden interior finish is desired. At present this material is more common in small or medium sized molded articles but may later be extended to include sheets. This material appears in finished state as a grainless and natural colored light wood. It cannot be easily colored by having pigments mixed with the powder but the final product can be treated to nearly any desired color or surface texture by the application of lacquers, wood stains, enamels, or mixtures of cotton or rayon lint in

(1) Uris, Auren W., Woodpulp Plastic Products, Modern Plastics, Vol. 19, No. 11, July 1942, p. 53

varnish. It evidently, therefore, is sometimes porous like plastic wood, and one defect is its water absorption when used without an exterior finish. Outer texture resembles sanded wood and is less smooth than synthetic plastics. Artificial graining and semi-painted effects can be produced by a process similar to that mentioned previously with reference to the knotty pine, but in such a case the labor and time considerations return and a form of imitation wood has merely been substituted for the natural wood. This plastic is about as strong as wood and can be drilled and punched, but not nailed.

3. Plywood

One of the largest uses for plastics materials is found in resin-bonded plywood formed by either of the methods previously described. (1) This material offers a cheap and easily acquired raw material for processing which, since it requires only a resin treatment, costs little more than ordinary wood. Its flexibility for forming and its veneering qualities, and hard and easily maintained surface make it particularly valuable for finishing purposes. Its market is constantly growing. Columns and walls in the massive rotunda of the Brooklyn central library were, within the last two years, surfaced from floor to ceiling with panels of resin-bonded plywood in a manner suggesting shelves of books. (2)

A similar use of laminated phenolics on a large scale (not plywood in this case) was made in a recently designed terminal for the Greyhound lines where, in addition to counter tops, the entire curved front face of the counter from top to floor is built of this material in

(1) See page 52
(2) Invading Interiors, Modern Plastics, Vol. 18, No. 7, March 1941, pp. 49-51

strips separated by contrasting-color extruded trim. Large round pilasters in this terminal are also faced from floor to ceiling with phenolic strips in tiers separated by trim. (1)

J. Plastics and Linoleum

In the architectural and building management fields where appearance, durability, or resilience of materials are factors, linoleum must be considered as a floor and wall surfacing material, and is likely to be less expensive than plastics, but much heavier. In addition to various floor designs and material grades, thin wall linoleum can be obtained which is more durable than oil cloth but which is made on a fabric base of the same type as the latter material. For floor covering the cork-rubber linoleum is more resilient than plastic tiles made with asphalt materials and the surface can be maintained with wax treatments. In spite of the dominance of linoleum and asphalt tile for certain types of floor surfacing there is, nevertheless, a definite opportunity for plastics floor coverings because of war material shortages and the adaptation of available materials to uses formerly monopolized by popular and low priced surfacings.

Narrow linoleum strip is frequently used as a contrasting insert with extruded metal or plastic ornamental strips in colors, in which case it becomes directly associated with plastics. During January, 1942, the Armstrong Cork Company announced a new line of plastics extrusion edgings and trim for floor and wall surface installations, the colors being ivory, gray, blue, brown, red and black. The company considers these plastics, probably Urea, as highly practical because of

(1) Invading Interiors, Modern Plastics, Vol. 18, No. 7, March 1941, pp. 49-51

strength, durability, color harmony possibilities, and ease of installation. (1) Adoption of plastics by this company, even though caused by immediate scarcity of non-ferrous molding strip, is of considerable benefit to the plastics industry owing to the importance of the company in its field. Use of plastics will bring the new material more effectively before the public and the construction industry. Other companies carry stock lines of urea or acetate extrusions besides their older metal moldings.

Owing to supply shortages, various fibres such as flax, wood, and rayon are combined with a smaller than usual percentage of wool for carpet manufacture; burlap and cork shortages are being compensated for in the linoleum field by reducing styles and eliminating unpopular colors. Such adjustments at least offer plastics a larger place among floor coverings. As stated in "Interiors" magazine: "New combinations of materials, new uses of available fibres and substances, and new ideas on the production front will be the manufacturer's offspring to take the place of former lines." (2)

K. Structural Signs

One of the great commercial opportunities for plastics is in the construction of structural signs for roof-tops and the faces of buildings. For day use, the colors and durability of phenolics are substantial considerations in choice of suitable media. For night illumination of the same sign, in addition to the reflection of light from the

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(1) Plastic Trim Relieves Scarcity, American Builder, Vol. 64, No. 1, Jan. 1942, p. 71

(2) Floor Covering Communique, Interiors, Vol. 101, No. 12, July 1942, p. 42

phenolics, sparkle and transparency can be given by acrylics in the form of glass-like sign elements.

An example of structural Plexiglas (Methacrylate) is found in a large outdoor sign erected in 1940 on Broadway, New York, in which eight tubular columns twenty feet long and three feet in diameter were constructed, the front halves of the columns being of Plexiglas and the rear halves of blue colored steel for strength and reflecting qualities. Each tube housed a fountain which was illuminated by colored floodlights. The tubes flanked a large glass bottle. Durable methacrylate sections 45" x 65" were used in this work, the sections being cemented together with transparent acrylic cement. (1)

L. Factory Remodelling

1. General

Industrial plant remodelling is fully as feasible in many cases as residential remodelling, new store fronts, or commercial interiors. Motives of necessity, expansion, installation of newequipment, process changes, opportunities for profit, or the need for maintaining position in an industry or for joining a civic improvement program may be the impelling reasons for a plant renovation job. The problems are considerably more difficult in these buildings, however, because of age and outmoded design, and the presence of a large amount of mechanical or process equipment which must be moved. Excellent results are being obtained despite these problems, in plant exterior modernization, executive office decoration, and shop layout.

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(1) Making Broadway Brighter; Modern Plastics, Vol. 18, No. 4, Dec. 1941, pp. 40-41

Glass block window walls with or without modernized window sash, combined with new door treatment and proper selection of line contours and direction, improve the actual appearance and create illusions of increased size. Main office interiors and lobbies present the same opportunities for renovation as do restaurant and specialty shops and at the present time afford the same outlet for plastics and wood veneers. In the plant itself plastics for decoration have less play since the improvements here concern modernized wiring, new machines, elimination of columns; even fluorescent lighting fixtures are of the sheet metal direct industrial type with exposed tubes. But there are opportunities in company restaurants, rest and recreation rooms, corridors and small architecturally impressive rooms, and, more extensively, in the operating parts of the new machinery.

2. Saran Industrial Tubes

A definite and appropriate use for plastics in industrial and public building construction exists in a way not so common in the other types of construction which have been discussed. Many chemical laboratories and industrial process plants as well as water heating and water distribution systems require piping made of various materials such as steel, brass, copper, or the ceramics. Plastic tubes of Saran (Vinylidene Chloride thermoplastics) have a unique use in place of copper and may be used in other instances as well. This flexible, semi-transparent tube is available in several small diameters up to 3/8". For chemical installations it is resistant to fire, moisture, brine, solvents, acids and alkalies, gasoline and various gases. It may be used at temperatures up to 250° F. for short periods and at pressures of 1500 lbs. p.s.i. In a

specific flexure fatigue test this material proved five hundred times as strong as copper. (1) The chemical resistance characteristics are similar to those of other vinyls. Since it will withstand medium temperatures it will be suitable for those chemical processes where medium heat is necessary to accomplish the required reactions, the resulting warm liquors flowing off to be cooled. Because of its transparency it can be used in processing to replace metal pipe which is often painted in various colors to indicate the liquid contained within. Saran will show the actual fluid without being colored and can be tinted where the liquid is colorless.

M. Furniture and Furnishings

One of the best chances at present for the publicizing of the merits of plastics is in the furniture and home furnishings market. Here buyers can obtain single pieces, small items, novelties to place in a particular spot, at reasonable cost. Furthermore, consumers are more concerned and more familiar with home-use products than with structural elements which, in their most imposing or fascinating examples, can only attract interest for the moment. The place of plastics in furnishings is constantly expanding and a few examples can only introduce this phase of the subject.

1. Methacrylate and Styrene

The beautiful transparent methacrylates and styrenes offer the most spectacularly modern effects. These materials were recently used in lavish form in the residence of a cosmetics manufacturer where custom designed furniture was installed. Here a dining set with 68" diameter

(1) Plastic Material to Replace Copper in Industry; American Builder, Vol. 64, No. 1, Jan. 1942, p. 94

round table and five chairs is entirely methacrylate with acid-etched flower designs. The entire head and foot rails of a bed are of the same material in scroll form with carved designs lighted by colored edge lighting which emphasizes the carving without being noticeable in the plastic. (1)

Smaller uses of this plastic elsewhere are found in spindle columns, rosettes, knobs, lamps, modern-style andirons and end tables. Many small examples resemble glass.

2. Cellulose Acetate Butyrate

Cellulose Acetate Butyrate (Tenite II) in flat extruded strips has been applied in basket woven form for a screen effect in cupboard door frames and for a baby's bassinet. Strips of this material are not pliable although more or less flexible and are therefore suited to semi-rigid purposes such as the one described. The door frames in this instance were of Formica.

3. Vinyledene Chloride

Pliable woven Saran, the same ingredient referred to in the foregoing pipe description, but basket woven as in the cupboard doors, is fabricated by the Heywood-Wakefield Company and has recently been applied by the New York City Board of Transportation to subway car seats as upholstery covers. (2) Since Saran is a member of the Vinyl Chloride family it is elastic and suitable for this purpose. Its other advantages are choice of colors, non-porous surface capable of being cleaned

(1) It's In Style: Modern Plastics, Vol. 18, No. 5, Jan. 1941, pp. 36-39
(2) Seat Covering of Box-Woven Plastic: Railway Age, Vol. 110, No. 2, Feb. 8, 1941, p. 288

easily, and absence of fibre splitting, which, in the case of natural rattan, tears the threads in clothing. For weaving it has the manufacturing advantage of continuous length which allows a better quality of woven fabric than is possible with short lengths of rattan or other fabrics.

4. Liquid Cellulose Acetate

A novel application of liquid acetate has been made in the case of curtains and more stable objects which may be coated with this solution known as "Shellflex". The coated objects acquire the merits of acetate plastics, being fire-resistant, acid and water proof, transparent or opaque, and capable of creating a glittering and sparkling spectacle when properly lighted. Variations in composition create a flexible film or a hard solid mass. It can also be made cheaply in plaster molds where mechanical accuracy is not important. The process has been used extensively in properties and stage settings for theatrical productions, but its field is much broader than this. (1)

5 . Film Veneer

Akin to phenolic veneer for furniture finishing with wood as the principal material, is a new laminated cellulose paper product which for certain effects makes use of a colored or photographic surface layer of paper to create the impression of texture under a transparent phenolic outer coating. The product may, instead, have an outer coating of colored opaque urea plastic. The finished material is of the nature of a plastic film being only .020" thick (less than 1/32") and is applicable as a veneer finish for wood, fibre board, or wall plaster, the latter making

(1) Lady in the Dark: Modern Plastics, Vol. 18, No. 8, April 1941, p. 34

it available for architectural purposes as well as for furniture. It has an astonishing array of qualities including: compressive strength twenty-four times as great as common woods; resistance to surface damage from heat, acid, scratching or impact; color fastness; electrical properties and light weight. It is warp and termite proof.

N. Plastics in Transportation

1. Railroad Cars

Certain special uses are made of plastics in the interior decorations of transportation units. On two trains added to the Southern Railroad's service in 1941 colored Formica was used for dining and club car table tops, for bar counter top and in certain elements of window framing. Ornate entwined vine design in similar plastic was used to frame the plate glass window behind the bar, and on side walls. Much of the trim throughout the various cars consists of aluminum or stainless steel and floor coverings are, in general, of linoleum, patterned. Fluorescent lighting predominates. The architectural use of color was enhanced by the choice of colors available in the plastics selected. (1)

2. Steamships

A new cargo vessel, the Robin Locksley, launched in 1941 for the American-African trade of the Seas Shipping Company, is the first of a fleet of six to be equipped with a variety of plastic materials. Some definitely well appointed cabins on board make use of methacrylate table lamps, chair arms and furniture handles. A unique clock face of the same material, edge lighted, was provided for the main buffet lounge. A total of more than two hundred ivory urea lighting fixtures is intended for the

(1) Deluxe Coach Trains Added to Service on the Southern: Railway Age, Vol. 110, No. 19, May 10, 1941, pp. 793-799

entire fleet. These are of semi-indirect type for wall use principally. Formica table tops serve the same purpose as has been mentioned for some of the on shore examples. Plastics have been applied extensively on recent shipping of other lines for their fireproof or fire resistant, rustproofing and easy cleaning characteristics. (1)

O. Electrical Fixtures

The immediately preceding examples of furniture applications for plastics illustrate their adaptability to highly finished small purposes of direct consumer interest. It can well be imagined that they would be equally adapted to common household fixtures or other fixtures of similar nature where color, transparency, safety or numerous special qualities are desired. Among the large uses for plastics is the lighting fixture industry and this means is afforded of helping to make consumers conscious of the value of plastics. Owing to the particular factors to be met and satisfied by lighting fixtures some attention should be given to the purposes of lighting and the suitability of plastics materials for meeting these purposes when used with artificial light sources.

1. Principles of Lighting

Artificial lighting may be considered as to: (a) purpose; (b) application of principles of physics; (c) type of illuminating element; (d) color principles. The general purpose of lighting is to render objects visible in darkness, but types of systems, methods, costs, and effects on health, eyesight, and ease of seeing are pertinent factors

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(1) S. S. Robin Locksley, Freighter DeLuxe: Modern Plastics, Vo. 18, No. 8, April 1941, p. 41

affecting the problem, as are size, distance, brightness, contrast, and color of the object lighted, physical and mental abilities and reaction times of the persons, and time available for seeing.

The amount of light required for various purposes is under constant study with reference to physiological and psychological reactions and from time to time the recommended quantities as measured by light intensity and other standards are changed, generally upward. Reasons for upward revisions include:

a. Economic advance: the availability of more light for less cost.
b. Scientific advance: improved mechanical methods and medical knowledge.
c. Unscientific merchandizing which sells more light than needed for a given purpose.

According to principles of physics light is either generated by a body or substance, or reflected, transmitted, obstructed, or absorbed by it. The giving of light may be the primary purpose of an object such as a lamp, or it may be incidental to some other purpose such as heating. These five effects must be considered, combined, eliminated, or emphasized in the use of light and these are the items which, with color, constitute the problems of lighting, beyond the fundamental problem of establishing the proper degree of seeing ease. These are the elements which, with cost considerations, affect the type of system, style of fixture, or luminaire as it is called, and use of materials in a lighting layout. They are also the design problems to be met in artistic display, in merchandising and sales appeal, and in the development of unique and pleasing architectural features.

The actual illuminating element in practical lighting systems may be carbon-arc electrodes, incandescent tungsten filaments (in vacuum

or gasfilled lamps), mercury vapor tubes, neon tubes, fluorescent tubes, or possibly luminescent plastics. These elements inserted in appropriate containers and combined in various ways as light sources, are further modified by numerous types of fixtures or architectural detail to produce systems and desired effects. Plastic materials find use in this connection as parts of fixtures and concealing detail, or actual tube elements.

The beauty, sales value, or practical features of a lighting system, or the use of light itself, is largely due to color effects and applied principles. Color may become manifest through the refraction of white light or through the use of objects which intercept light rays and absorb most of the color elements in the ray while reflecting only those which appear to give the characteristic "color" of the object. The color of the object may be due to the presence of a die or pigment in the object, which reflects the observed color.

In refracted light the actual colors in the ray are noted. The particular colors are dependent on the material emitting the ray. Sunlight or white light contains all the colors in varying degrees. Invisible light such as the ultra-violet ray may be transformed into visible light by passage through the proper element. Thus in fluorescent lighting powdered or "pasted" phosphors such as zinc silicate, calcium borate, or magnesium tungstate, when applied to the inside of a glass or acrylic resin tube produce various colors, to be brought out only when the tube is illuminated.

2. <u>Advance in Fluorescent Tube Manufacture</u>

A decidedly important development in fluorescent lighting is the inclusion of the fluorescent powders as ingredients in the pill made

of cellulose acetate- or possibly styrene-base powders so that the finished plastic tube or sheet contains the fluorescent element uniformly distributed throughout, rather than having it painted on an inside surface as was the method with early glass fluorescent tubes. Better distribution, greater light intensity, and a more positive and durable product results.

3. Luminescence

The principle of luminescence has also been applied in plastics manufacture for architectural and lighting purposes. This principle, briefly, is the development of glow within an object after being subjected to light rays from an external source, so that when the rays are removed, as at night, the object will give up light of its own accord in the form of glow. Such glow is useful in detecting the object, but the power to glow must be replenished from time to time by exposing the object to more external rays. Luminescent powders may be mixed with the plastics ingredients, as with the fluorescent powders, so that when the plastics product is finished it can store light energy during the day when the article, such as a light switch cover plate, is in ordinary use, giving up light as a glow at night of its own accord to guide persons to the switch. The plastics plate thus becomes more useful. This method of providing luminescent products superseded the former method of radium painting. One interesting use of such plastics is for nursery shapes of favorite animals fastened on walls or furniture in children's nurseries on the theory that they will comfort the child should he wake during the night. (1)

(1) Lichtenberg, Charles, Luminescent and Fluorescent Plastics: Modern Plastics, Vol. 18, No. 7, Jan. 1941, p. 45

A reverse application of fluorescent lighting occurs when the powder-containing plastic is acted upon by light from an external source rather than from a light source contained within the plastic body. Fluorescent lighting tubes are examples of light source contained within the body, the light apparently being given off by the tube. The reverse method develops when the fluorescent body receives rays from another source and becomes illuminated. This principle is used in dark interiors as for aisle lights in theaters where invisible violet rays (black light) act upon the fluorescent plates attached to end seats, the rays at the same time being invisible to the audience.

4. Lighting Systems

Lighting systems, in general, consist of: (a) direct, in which all light is directed downward by metal shades; (b) semi-direct, in which glass or plastic globes diffuse the light in all directions; (c) semi-indirect, in which over 90% of light is directed upward; (d) indirect, in which all light is directed upward, and reflected downward by the ceiling.

5. Lighting Reflectors

Reflectors in lighting are of two general types, both used for the purpose of directing rays. The common types found in search lights and automobile headlights, for example, are intended to direct a beam of light for a definite or maximum distance. They consist of a concave or parabolic-shaped metal or glass piece, highly polished and possibly silvered. Such reflectors also find use in floodlighting, theatrical spots, and in supplementary lighting to emphasize commercial display or to provide intense light for industrial inspection or office use. The common architectural reflector, however, is that part of the lighting

fixture which reflects light as in the metal discs of indirect luminaires, or which diffuse light as in common opalescent globes used for semi-direct lighting, these globes being the most common medium for economical and ordinary lighting systems for general interior use. The opalescent globes are made of translucent glass, the efficiency of which varies with the particular glass or manufacturing methods. Parchment paper shades often supplement glass reflectors to control glare or to add atmosphere in particular applications.

6. Place of Plastics in Lighting

The field of plastics in lighting includes at least three major functional applications and one minor one. As previously indicated, the first primary functional use is in the lighting element itself, the fluorescent tube. A second major application is in semi-indirect type lighting fixtures where translucent properties are of value in the reflector. A subsidiary application of the translucent property is in panels applied to wall and ceilings or proscenium arches, etc. to produce luminous effects from lamps placed behind them. The third major application is in plastic luminaires where elements other than reflectors alone are made of plastics. In these applications opaque colored plastics are used emphasizing mechanical or artistic properties appropriate to the application of the plastic. The minor use of plastics in lighting is for the most part in the transmission of color as in the case of traffic signal discs.

Before describing the plastic materials adapted to these various uses it is desirable to review the properties required of the materials for these purposes. Depending on the specific application the plastic

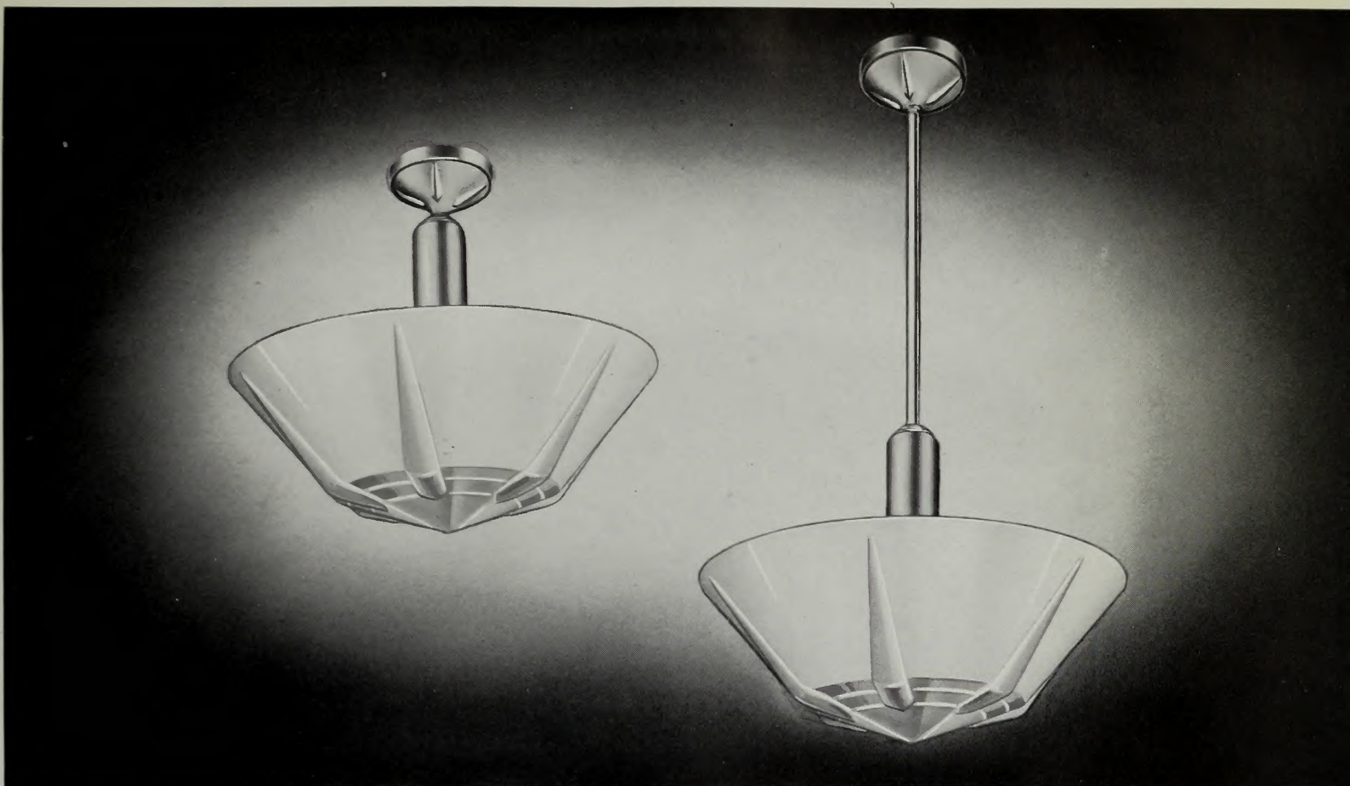
should be: transparent--natural or clear--translucent, colored, light in weight, moderately strong, have high dielectric, be fireproof or fire resistant, capable of holding shape under varying degrees of heat, capable of holding original color with aging, possess ease of molding or ease of machining, and be comparatively cheap in comparison with other plastics or competing materials.

Owing to the nature of the plastic object and its subjection to heat changes, even though comparatively low heats, the field is limited for the most part to thermosetting plastics. The phenolic or urea base resins are most suited, the former for supporting or for artistic parts where opaque elements can be used, and the latter for reflectors or translucent elements; examples of urea base reflectors being the so-called Beetleware or Plaskon types as illustrated. Urea sheets in the form of small panels are used for the sides of fluorescent luminaires where they perform the same function as the globular reflectors of the semi-direct incandescent systems. Ureas are also used for translucent skylights and for architectural luminous panels in walls. Cellulose Acetate in proper form is also suitable for these general purposes.

Transparent acrylics, Methyl Methacrylate, can be used in tube elements for fluorescent tubes, although theoretically, as a thermoplastic material, it should not be. Moreover, this type of plastic shrinks over a period of time. If prepared in such form as to be "clear translucent", acrylics are colorless yet not transparent and can then be used with or without fluoride etching as a semi-direct lighting reflector, especially in fluorescent luminaires.

In a recent design of semi-direct fluorescent luminaire, variation in light distribution was obtained by varying the thickness

THE COMMODORE



No. 3483 No. 348

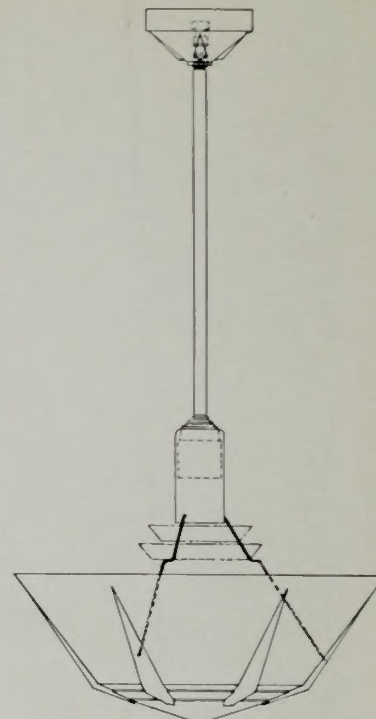
1. Designed by one of America's foremost industrial designers.
2. Reflector is molded from Plaskon, 18" in diameter. Vertical elements are molded into the reflector for decoration and to add mechanical strength.
3. Husk, stem, and canopy manufactured from heavy gauge aluminum. All exposed metal parts finished satin aluminum.
4. Suspension type is equipped with the exclusive Wakefield socket cap whereby the stem can be shortened on the job with no more equipment than a hack-saw and screw-driver.
5. Provides excellent semi-indirect illumination for easy seeing.
6. Standard units for classroom and office use.
7. Units carry the inspection label of the National Board of Fire Underwriters.

Catalog No.	Description	Wattage	Color	Diameter Reflector	Socket	Length Overall	Stand'd Weight	Package Quantity
3483	Commodore	300-500	Cream	18"	Mog.	18"	8	1
348	Commodore	300-500	Cream	18"	Mog.	34"	8½	1
3487	Lamp Shield						6	12
3481	Commodore Demonstrator	300-500	Cream	18"	Mog.	34"	12	1

Fig. 12

Typical Installation of
WAKEFIELD COMMODORES

A white acoustically-treated ceiling provides the reflecting surface for these Commodore units. The attractive appearance of these highly efficient luminaires go far in contributing a thoroughly modern appearance to this office.



Cross-section No. 348

LIGHTING DATA

To serve as a guide for similar installations

Mills Building, San Francisco

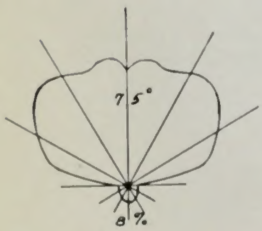
Luminaire.....108 No. 348 Commodore Units
Area..........................170' x 48'
Mounting............34" overall suspension
Lamps......300 watt I.F. Mazda, mogul base
Ceiling Height......................11'-2"

Interior:
- Ceiling.............Sanicoustic White
- Walls....................Dark cream

Illumination:
- Under units..............20 footcandles
- Between units...........18 footcandles
- Average................19 footcandles

GENERAL LIGHTING DESIGN DATA

The table given below indicates the number of square feet allowable per luminaire for varying interior conditions and for specific levels of illumination. To find the number of units required to light a room, divide the total square foot area by the proper figure chosen below. Figures are based on present databook ratings. Light finish means a ceiling reflection of 75%, walls 50%; medium finish indicates ceiling 50%, walls 30%.



				SQUARE FEET PER LUMINAIRE					
				Large Room Width 4 times height		Medium Room Width 2 times height		Small Room Width equals height	
Catalog No.	Lamp	M.F.	Average Fcs. In Service	Light Finish	Medium Finish	Light Finish	Medium Finish	Light Finish	Medium Finish
348	500-W	.65	20	136	88	101	66	76	48
	I.F.		30	100	65	78	48	55	33
			40	75	49	59	36	41	24
			50	60	39	47	29	33	20

PLASKON LIGHTING REFLECTORS

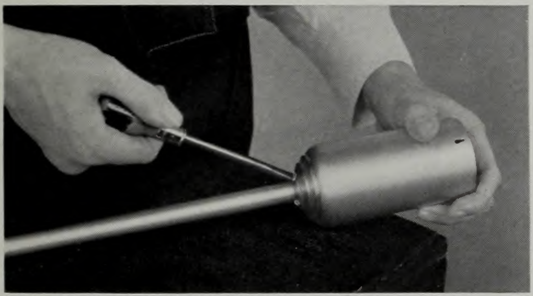
Plaskon is a urea-formaldehyde molding compound, which, when placed under intense pressure and heat, polymerizes to form an infusible and insoluble material. The presses in which this material is molded produce a maximum pressure of 1750 tons. The molds, of which the largest weighs approximately 5 tons, are highly polished so that the reflectors come from the press with a mirror bright surface which is incidental without additional labor.

PERMANENCE . . .

As long as Wakefield units are hung without any change in construction after they leave the factory, and are properly maintained while in service, Plaskon reflectors are warranted not to deteriorate. Units operated at room temperatures averaging 121° F. showed no sign of deterioration at the conclusion of a test conducted over a 28 day period. Further details of this test may be obtained by asking for Electrical Testing Laboratories' Report No. 138848. Plaskon will not support combustion and will only char when submitted to high temperatures.

SHORTENING DEVICE . . .

The lightness of Plaskon reflectors permits the use of the special Wakefield socket cap



whereby the stem can be shortened on the job with only a hack-saw and a screw driver.

Lengthening can be easily accomplished by means of stem sections with internal couplings and ornamental discs for hiding the break.

EFFICIENCY . . .

Plaskon reflectors have favorable prime costs and high reflection factors. In fact, units using Plaskon reflectors have some of the highest efficiencies ever recorded in the lighting field, incorporating at the same time advanced lighting practice with low surface brightness for the avoidance of glare. Readings between 85% and 90% are not uncommon with this type of equipment.

SURFACE BRIGHTNESS . . .

By controlling the density of the molding powder, surface brightnesses as low as 0.24 candle power per square inch have been produced. Using this method of control, units using Plaskon reflectors can qualify either as semi-indirect or indirect lighting units in accordance with the accepted definitions of these terms. In Wakefield units, high efficiency readings are often sacrificed to obtain low surface brightness for comfortable seeing without glare.

COLORS . . .

The molding powder itself is available in a myriad of colors. Only a few of these, however, are adaptable to the lighting field. The colors which are standard and which are listed in this catalog are shades of ivory and white and were selected after exhaustive tests involving efficiency, visual acuity, surface brightness, and current trends in the lighting art. Any color once supplied can be accurately duplicated at any time.

CONTROL OF THICKNESS . . .

Reflectors are molded in steel dies made in the finest tool shop in the country. The dies are heat treated to make them as hard as possible. Once the thickness of a reflector has been decided upon, the same thickness can be maintained as long as the dies are in use. This feature insures the same color of reflector even though they may be ordered at long intervals apart.

INSPECTION . . .

Wakefield molded plastic reflectors are inspected when they are removed from the molding press and again before they are shipped from our plant as a complete unit. Packed in specially designed containers, they have earned a reputation for extremely small breakage while in transit.

AVAILABILITY . . .

Plaskon reflectors, merchandised under the names of Ivoryglow, Commodore Directlight and Downlight, and the Commodore, are available through various recognized distributors as complete lighting units bearing the "Red Spot" identification label. Stocks are carried in all principal cities in United States and Canada.

CLEANING . . .

If reflectors are dusted on a regular schedule, their original efficiency will be maintained over a long period of time. Reflectors should be taken down at definite intervals and thoroughly washed. This schedule should be varied to meet individual conditions. A warm soap solution containing any mild water softener such as tri-sodium phosphate, Borax, or Calgon is recommended as the best cleaning agent.

RESILIENCY . . .

Plaskon reflectors are highly resilient, withstanding rough usage without permanent deformation or rupture. Although Plaskon reflectors are as hard as steel, they will break when submitted to unusual sudden shocks.

PERFORMANCE TABLE

In reading these figures, the following lighting concepts should be borne in mind:

LOW SURFACE BRIGHTNESS . . .

Surface brightness should be sufficiently low to prevent glare from the reflector.

OVERALL EFFICIENCY . . .

For an economical lighting installation, a high overall efficiency is essential. High efficiency readings are often sacrificed in Wakefield units, however, in order to keep the surface brightness figure low.

DOWNWARD AND UPWARD COMPONENT . . .

The ratio of the downward and upward component determines whether the unit can be classified as a semi-indirect or indirect unit. By varying the density of the molding powders, the same size reflector can often qualify for both of these categories.

Classification*	Approximate distribution of Luminaire Output	
	Upward	Downward
Indirect	90-100%	0-10%
Semi-indirect	60-90	10-40
General diffusing	40-60	40-60
Semi-direct	10-40	60-90
Direct	0-10	90-100

* Based on I.E.S., A.S.A., and A.I.A. definitions

Cat. No.	Diameter Reflector	Lamp Used	Color	Surface Brightness Candlepower per Sq. In. Min.	Max.	Distribution of Luminaire Output Downward	Upward	Overall Efficiency	Classification
245	15"	300 W-IF	Cream	0.4	1.5	10.5%	73.5%	84.0%	Semi-indirect
275	15"	300 W-IF	Cream	0.5	2.6	17.0%	67.0%	84.0%	Semi-indirect
265	15"	300 W-IF	White	0.4	1.8	12.0%	71.0%	83.0%	Semi-indirect
*348	18"	500 W-IF	Cream	0.5	1.6	10.0%	70.0%	80.0%	Semi-indirect
348	18"	500 W-IF	Cream	0.5	1.4	8.0%	75.0%	83.0%	Indirect
379	19"	500 W-IF	Cream	0.4	1.9	13.0%	70.0%	83.0%	Semi-indirect
369	19"	500 W-IF	White	0.3	0.8	6.5%	75.0%	81.5%	Indirect
763	23"	750 W-IF	White	0.2	1.0	5.5%	73.5%	79.0%	Indirect
106	26"	1000 W-IF	White	0.1	0.6	3.5%	69.0%	72.5%	Indirect

*Tested with Lamp Shield No. 3487

of various parts of the single piece Vuepak (Acetate) reflector during molding so that the thinner bottom strip emitted the maximum light for use directly under the fixture, while the thicker sides served to diffuse and soften the light rays at either side and prevent glare which otherwise might annoy persons at a distance from the fixture. In another type of plastics fluorescent reflector, sheet made of acetate and called "Louvreglas", a clear panel, was produced which allowed direct light immediately below the fixture. Diffusing ribs of the same plastic in translucent form, plain or colored, were formed in the clear sheet in louvre form to prevent glare from affecting persons at a distance from the fixture.

In the modernization of several lounge cars in 1940 the New York Central Railroad installed fluorescent lighting troughs throughout the length of the lounge section using plastic diffusing panels. For dimmer use during night hours incandescent lights were located between the adjacent lengths of fluorescent units, making use of the same plastic diffuser. The outside monogram name plate at the rear of the train was illuminated by red fluorescent lights.

7. Glass and Plastics Reflectors Compared

As compared with glass for lighting fixture reflectors, suitable plastic equipment has these advantages: (a) two-thirds to three-quarters lighter weight; (b) easier and safer handling and shipping; (c) easier machining qualities during fabrication and assembly; (d) flexibility which allows the reflectors to be snapped into place in metal grooves. For fluorescent lighting urea may be used as previously indicated for incandescent lighting. (1) In addition cellulose acetate

(1) See page 102

is suitable for the former type of lighting owing to the small amount of heat developed by such illuminating media. The relative values of standard commercial thicknesses of urea plastics and glass reflectors are shown in the following table:

TABLE NO. XV

EFFECT OF BOWL THICKNESS ON LIGHTING CHARACTERISTICS OF GLASS AND UREA REFLECTORS

Material	Thickness	Reflector	Translucent	Total
Dense White Urea	.060"	83%	8%	91%
Alabaster Glass	.189	70	14	84
Medium White Urea	.048	70	20	90
Opal Glass	.240	70	10	80
Translucent White Urea	.048	54	40	94
Cased Opal Glass	.146	54	30	84
Configurated Glass	.257	12	76	88
Translucent Alabaster Glass	.245	50	32	82
Translucent Urea	.048	50	40	90

Source: Modern Plastics, Vol. 18, No. 4, December 1940, p. 31

Transparent colored phenolic resins of the Bakelite variety are especially suitable for traffic light discs and other applications requiring transparency and resistance to abrasion. The stock colors of this type of plastic are amber, green and ruby.

Where the entire luminaire is plastic it usually is necessary to have concealed metal support in the stem for strength, but the canopy and exterior of the supporting element together with the reflector, if of the indirect type, may be of opaque Bakelite material such as Durez, Durite, or Resinox, or the luminaire as a whole may have its elements of transparent, translucent, or colored opaque plastics in a design calculated to enhance the artistic appearance of the fixture. Polished metal ornaments or colored plastic inserts or embellishments may also be applied.

These latter plastics may be of thermoplastic material such as cellulose acetate or styrene. The reflector element of this plastic "masterpiece" would probably be translucent urea Beetleware if the fixture were the common semi-direct type.

P. Summary and Conclusions Regarding Architectural Uses

With all the foregoing examples of plastics for architectural purposes only impressions can be gained as to their field of possibility. Instances have been given to show the extent of their uses and the variety of materials characteristics and types of materials available. Other instances along similar lines could be given but would undoubtedly stress the same major uses as have been brought out with occasional novel applications dependent on the imagination and ingenuity of a particular designer who was fortunate enough to find a plastic which would meet his needs in physical characteristics, cost, or size.

In general it appears that for architectural purposes plasticized plywoods now enjoy the greatest single demand and largest opportunity for mass production, with extrusions for ornamental decoration following, and with phenolics in use for specialized sheet purposes such as table tops. Crystal acrylics for ornamental glass substitution are still in the luxury class. Vinyl types for waterproofing and flexibility are growing in special fields. Considerable demand for plastics materials is found in specialized manufacturing fields such as lighting equipment. On the whole the industry is quite young, products are still used sparingly for relatively unimportant purposes except in rare instances when some man of vision, courage, or financial ability proves the real plastics value by designing or ordering a large scale installation where the material stands out on its own merits.

From the instances given one would believe these limited uses to be the actual status of the industry with reference to construction and decoration were it not for certain facts: (a) many of the examples cover construction over two years old; (b) most of the larger and varied applications have occurred within two years or even one year, indicating rapidly developing confidence and demand; (c) the industry as a whole became of public interest only since the World's Fair of 1939 and 1940; (d) creation of basic materials shortages during the present war. It is to be expected, therefore, that extremely rapid development will take place (a) through war's necessity; (b) through further development of professional and technical confidence in the structural value of plastics; (c) through demand from an accustomed public. Time is necessary to promote the product but far less time is needed today than would ordinarily have been required.

But with the great variety of qualities possessed by various plastics it is apparent that other fields of endeavor than construction and architecture might find these products to their advantage. If it be assumed that the industry as an entity is constantly searching for greater opportunities to promote plastics for consumer benefit, because demand must come directly or indirectly from consumers, then it would be appropriate to make numerous consumer articles which, while being of genuine value, would serve as samples for public consideration. By applying plastics in commercial display these materials are indirectly brought before the public in such a way that they will be seen and will cause comment. By applying plastics in packaging they are brought directly before the public in such a way that they will be taken home

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and become the basis of personal experience with the materials,thus developing acquaintance with the entire field. The resulting repeat uses and ultimate demand will bring about the needed cost reductions which will enhance the position of plastics in larger structural uses.

To catch a glimpse of plastics as presented for consumer use, therefore, our attention can be turned to display and packaging as examples of modern merchandising.

SECTION VI - PLASTICS IN DISPLAY AND MERCHANDISING

The logical approach to display and packaging is through the front door of the store after having first paused to consider the store windows, since commercial merchandising begins at the sidewalk. What it takes to get the customer on that particular part of the sidewalk could be classed as circulated advertising and does not apply directly to the purposes of this thesis. Once inside the store the interior displays and variety of packages can be noted and the skill with which their various appeals are set forth are measures of the merchandiser's ability.

A. Development of Store Windows

In the design of store fronts there are many architectural features with respect to materials, trim, and structure of the building as a whole, but the important and practically basic object is merchandise display which is accomplished by the type and size of store window. Windows have passed through an evolution and today are the subject of professional controversy which is closely allied to display theories in merchandising.

In past centuries craft displays by the home workman, if made at all, could only be made behind the lattice windows of the shop, and very little emphasis was placed on methods. In more recent times the window has appeared as a miniature of the country store, samples of the entire stock-in-trade being displayed simultaneously and with varying degrees of formal arrangement. Typical structurally small windows of the period sufficed for this purpose. Next, moving objects, not always related to the store's wares, appeared in the window.

Later the present common type of department store window with adequate lighting was developed but expert window dressers and decorators tended to overemphasize details and surroundings in carrying out a setting or background, thus risking the loss of the particular advertising message. Nevertheless, successful window display method had arrived with the advent of the scene development. But narrow store-frontage, narrow windows, and store entrance requirements limited the opportunity for a varied display. The immediate solution was either the recessed store entrance or the arcade construction which allowed window depth leading to the door but reduced the net inside floor area. This condition, together with the tendency to prevent any chance of seeing into the store because of the window backers, has led to the most recent and modern of windows known as the "Open Faced Shop" which consists of a modernly treated and properly proportioned plain plate glass window having its inside sill the full width of the building's wall thickness, thus allowing unobstructed view of the store interior. (1) Only a few small items are placed on the sill; the success of the merchandising effort being dependent on the skill and artistry of interior store layout.

The important external factor is the window proportion as related to the building facade and the size and type of product which the store sells. Internally, however, there is added opportunity for: (a) effective store and display design; (b) lighting advantages; (c) adequate display of a large variety of items; (d) creation of atmosphere which will be conveyed to the shopper through the window by the quality and choice of store furnishings and lighting; (e) added life, excitement,

(1) Ketchum, Jr., Morris, <u>The Open Faced Shop</u>, Interiors, Vol. 101, No. 12, July 1942, pp. 44-47

motion and interest caused by the sales force and customers inside. By using a store front of this type all the plastics applications within the store including the products, become part of the window. Whereas racks, holders, nameplates, background, inserts, signs and other plastic-modernized conventional display equipment was formerly either in the window or in the store, it may now be in both at the same time. This allows infinitely increased chance for a larger number of devices to be employed throughout the store and their colors, transparencies, reflections and forms can be emphasized, with due regard to the merchandise, by the additional lighting facilities in the store. These new windows are designed to allow temporary adaptation to the earlier forms of conventional store window with backboards, etc. Some types of business cannot use the open faced store window effectively and there is always the practical consideration of rearranging the entire store to maintain customer interest, whereas formerly only the windows required attention.

B. Elements of Interior Display Motives

Inside the store effective merchandising requires a knowledge of the purposes of display. The fundamental elements of display include: (a) attracting attention; (b) arousing interest; (c) creating desire; (d) impelling action; all for the purpose of making a sale. Factors which aid in attracting attention and creating interest are: (a) arrangement of merchandise; (b) color; (c) live models; (d) motion; (e) novelty; (f) lighting; (g) effective or unique signs; (h) timeliness.

Durable displays may be purchased but alert merchandisers and creative assistants can produce home-made displays of miscellaneous materials. Choice of color is of great importance in selling a point

and where this form of presentation is used plastics have an advantage where their color variety can be capitalized. This feature carries over into the actual product design of many small personal and kitchen items used particularly by women.

Many counter and shelf displays require unique and interesting features in order to retain their place on the retailer's shelf. Other similar displays must combine taste and quality with their message when in the form of placards or racks to be used in first class shops or with specific store interiors. Design ability and knowledge of both product and distributing agency stand out as essentials of display advertising. Window displays require similar abilities and knowledge. The proper and adequate use of plastics, to exploit their full values and merits as advertising display media calls for alert designers who must keep abreast of the times and merge the new means at their finger tips with their knowledge of the advertised product and the requirements of the agency.

C. Self-Display by Products on Sale

The idea of using plastics products to display themselves may be carried out, in the case of large items, through the use of panels made of the plastic, or of other panels containing attached plastics pieces, shapes or articles of merchandise, and arranged on vertical or horizontal racks. Small architectural wall sections or other practical sections or elevations appropriate to the use to which the plastic is being put can be built on the show room floor as in the case of building materials. Easel and wall displays of colored photographs showing actual installations of the plastic may also be placed in the store. Proper

attention to principles of advertising, display, store layout and merchandising practices combined with the variety of plastic materials, their colors, and uses, offers opportunities to borrow display methods formerly used for other products and to adapt them with improvements to the adequate display of plastics.

Another method of using the product itself in the display is shown by the 1942 version of the counter show card display. The Gits Molding Company attaches actual plastics products (electric light-wall-switch covers) to cards for counter display. Although this means of displaying merchandise is not new it brings the plastic product directly before the customer. This display presents types of covers in various plastic colors and luminous plastics and imparts an advertising message on the card. The luminous plates are examples of the luminescent type of plastics.

A unique application of plastics in counter display signs is that in which a translucent plastics sheet is bent into a semi-circular form and attached to a base containing a tubular fluorescent light. The ends of the sheet are covered by opaque pieces standing upright at each end of the base. An advertisement or an appropriate scene or trademark, or brand name, may be painted or printed on the plastic and will be emphasized by the light. These designs can be changed from time to time.

D. Merchandising Through Containers

Today's packaging methods represent a great advance over the old fashioned open bulk method. Formerly the real value of packaging was overlooked and was associated mainly with artistic design, beauty, and sales appeal for a limited group of specialties. But the basic

purposes of protection, honest weight, preservation of aromas, prevention of shrinkage and evaporation, and time saving through reduction of wrapping time in retail stores are among the real objectives of packaging. These points are more in line with the new principles of functional design and purpose, this being a goal which pervades the whole field of modern design whether it be buildings, automobiles or clothing. Today's products are built around efficient use and the trim is secondary except as it emphasizes the main purpose. During a war economy, functional packaging becomes even more important owing to changes in available materials and the need for durable containers to withstand the harder handling in transportation. In shipping spoilable products considerable waste is prevented by effective packaging.

E. Packaging Materials

Packaging materials have included many of the metals, glass, paper, cloth, wood, fibres, and now plastics are entering, having arrived in some smaller examples of container parts such as caps and closures. Molded package closures of phenolic or urea base for the opaque type of cap, or styrene for the transparent variety of artistic stoppers common in perfumes, offer advantages of durability, strength, color or transparency, and chemical resistance, as compared with cork, glass, or printed metal. These closures may be designed also for convenient use as applicators for the substance contained in the jar, of which they are a part, in a manner similar to the glass stem on an Iodine bottle stopper. There is a growing place in displays and in closures for cast phenolics which up to the present time have been less used than molded phenolics. The advantage of these in addition to their transparent colors is their

manufacture at atmospheric temperatures and pressures rather than the high pressures of phenolic molding. Certain equipment costs are thereby eliminated.

1. Woodpulp Plastics

Woodpulp plastics, mentioned among the architectural applications, are also commonly used in packaging and display fields for their light weight or cheaper production costs. (1) Furthermore, exact dimensions and mechanical tolerances are not as exacting in the majority of display pieces, and woodpulp plastics, which do not excel in these qualities, are suitable for such purposes. In one instance a perfume container base made of woodpulp plastic reduced shipping weight of the product by thirty-six pounds per gross as compared with former cast metal base. In the case of a small order for one thousand display pieces molded woodpulp provided a cheap medium because the mold could be made less expensively in bronze than in steel which would have been required had synthetic plastics been the chosen material for the piece. The shape of the piece prevented use of an ordinary wood turning. It is stated that where a large number of small objects are to be made injection molding of synthetics would be cheaper, but where only a small number is required the low cost of molds for the pulp product is an advantage. Pulp as a materials factor is cheaper than synthetics for larger sized products. Since pulp threading required for assembly of two or more pieces is not accurate, it is necessary to use metal inserts which contain the threads. (2)

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(1) See page 86
(2) Uris, A. W., Wood Pulp Plastics, Modern Plastics, Vol. 19, No. 11, July 1942, p. 53

2. Transparent Wrapping Papers

For packaging there are a number of transparent wrappers. Among them are two types of Cellophane (Cellulose), a plain type which is quite subject to shrinkage and wrinkling from atmospheric moisture, but is the cheapest of the transparent wrappers, and a moisture-proof type, more expensive, but also more resistant to moisture. Cellulose acetate in film form costs about the same as the moisture-proof Cellophane and while not entirely moisture proof it does not shrink and wrinkle appreciably from age and moisture.

The Neoprene type of hydrochloric-acetylene elastomer is also transparent and suitable as an elastic packaging wrapper which is more durable and waterproof than the group of celluloses mentioned above. Vinyl plastics, rubber-like and transparent, also, cover the field of wrappers. These may also be formed into complete semi-rigid containers which will not change shape with temperature changes. Their use, however, requires definite knowledge of the chemistry of the packaged product in order to be certain that the packaging material is the proper one for the given case.

At the annual "5 & 10" Packaging Conference Show in March 1941 half of the twenty-eight awards were made to devices employing transparent wrappers, many of which were plastic. (1) The object of this annual conference is to consider the merchandising methods of syndicate chain stores. The theme of one packaging address particularly applicable to transparent plastics was: "Products that Live in Glass Houses Soon Find New Homes", bringing out the value of transparency in packaging.

(1) Slaughter, P. B., Packaging for the 5 & 10, Chemical Industries, Vol. 48, April 1941, p. 470.

3. Cellulose Acetate

Cellulose acetate is frequently used in the cosmetics packaging branch as an enclosing cover for perfumes, powders, sponges and powder puffs which are displayed under the transparent plastic in bottles, cardboard boxes or as exposed products visible through the plastic. In some cases only the top of the container is of this plastic, the base being of wood or cardboard.

F. War Shortages of Metals

Present materials shortages have fully as important an effect on package design and the package making and advertising industries as they have on other industries. It is surprising to find the same material difficulties in this field as in the building field. The war metals were formerly used in the packaging business as wrapping foils for candies, tea, and other similar products; for paint pigments; chromium and titanium formerly went into coloring dyes for designs and trade-marked wrappers, as did zinc, naphthalene, analine dyes and cobalt. Even formaldehyde, the important Bakelite ingredient, was also an ingredient of advertising ink used to print wrappers and labels. More recently a plastic base material, Aruba Bitumen, which acts like a thermoplastic, has become an important ingredient of printer's ink and is, therefore, closely associated with advertising and with printed display pieces. (1) This element made from Venezuelan crude oil replaces the heavy oil constituent in the ink formula. Its principal advantage is its capacity to set after the printing, much as a thermoplastic does on cooling, thus preventing smearing of printed matter on a page. Bitumen plastics have been previously

(1) Business Week, March 22, 1941, p. 62

mentioned in this thesis in connection with cold molded objects. (1) Shortages in these materials are not acute at present.

An outstanding material in the packaging field has always been glass as used for jars. It is now under further consideration to replace the tin can as a container product. Other current methods for supplanting tin include the bonderizing of steel which does away with tin plating, and the direct application of vinyl acetate or polyvinyl chloride as an interior coating on steel cans to save tinning. "D. P. Solution", a development of Merrimac-Monsanto Chemical Company, is similar to these plastics and is applied to drums used in the shipment of clear lacquers, alcoholic shellacs, collodion, and pyroxylin. When mixed with the transported material before being placed in the metal container the solution later separates and coats the drum interior, thus preventing rust. The solution is not suitable for the shipment of all chemicals.

G. Glass Jars

Where glass is used for containers it encounters two objections: (a) need for adapting retail store facilities for display and for wider shelving, owing to size of jars, and because of accidental breakage by customers; (b) difficulty of concealing inferior grade products in the jars as could be done with the opaque tin cans. Some success has accompanied the use of jars by packers, and foods packed in jars appear to meet ready disposal when adequate salesmanship is used, but since many products can be successfully distributed by aggressive salesmanship it cannot be said that jars are more easily sold merely because they are jars. It is maintained that they are especially

(1) See page 35

successful in super markets where large displays can be arranged. The available floor space for tables then takes the place of the larger shelves needed for the glass stocks. Glass has the advantage of being available for home use after cleaning, and attractive colored jars can be made by the creative housewife by application of some bright plastics paints.

H. Plastic Containers

As a substitute for glass jars or metal cookie boxes the Transparent Specialties Corporation, as of February, 1942, announced a cylindrical plastics cookie jar about 6" x 6". Strangely, however, this container has a metal base and a screwed metal lid, also a metal handle. These elements of design in many other instances are of plastic while the body is glass or metal. The advantages of plastics for this purpose as compared with glass are: reduction of tendency to break; less weight when added to the grocery bundle; ready colored for miscellaneous home uses without further preparation. The re-use value of plastic containers in general can be enhanced by a unique or attractive shape as is now practiced with certain glass jars for preserves.

With reference to the effect of war requirements on this section of the packaging industry, plastic containers are considered somewhat of a substitute medium still in the development stage, and little serious help is expected from plastics even in the closures branch where it is extremely necessary to find a replacement for metal lids. Paraffin-treated papers are being tried and paint products in cardboard containers are now on the market. Formerly such containers were only used for quick retail food sales where the carton would be opened soon

after the sale. Melamine plastics have found a use as coating in the preparation of these cardboard containers.

Glass continues as a container in its former applications but the variety of shapes and sizes is being reduced by standardizing methods as a war measure.

I. Food Packaging

Vinyl and acetate have been used in several forms of packaging. Where acetate has been used in direct contact with foods, tobaccos and similar goods it was chosen because it was odorless, tasteless, unbreakable, possessed dimensional stability and was practically moisture proof, all of which factors are essential for food containers. Canisters made of this material can be used in the home when empty. They have merchandising appeal when showing the products in retail stores without the aid of display devices, and in some instances may be refilled in the store as store equipment, thereby acting as a small bin for the transparent display of dry, loose products such as cookies. The visibility quality has been available in the past for years in glass jars but the safety value and light weight of plastics are relatively new on the market and this will continue to add merchandising value in the future. (1)

Vinyl rubber bags are in use in the frozen foods industry for packaging frozen foods, principally liquids. Food is placed in the bag and the sealing is done by twisting the top of the bag. The twist is retained by being in contact with the cardboard outer container. The bag stretches when the freezing process expands the contents, thus

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(1) Modern Packaging, Vol. 14, Dec. 1940, p. 60

eliminating need for an expansion air space in the bag, which is a packing advantage. After defrosting by the consumer the contents of the bag are easily poured out. (1)

(1) Scientific American, Vol. 164, April 1941, p. 224

SECTION NO. VII - SIGNIFICANCE AND FUTURE OF PLASTICS

Plastics have been considered by some authors as establishing the grounds for a twentieth century industrial revolution as far reaching as the old nineteenth century industrial revolution, but having the advantage of improving the ultimate living standards of workers without requiring the former degradation of immediate living standards. Labor may, however, remain fully as degraded from the standpoint of skill requirement as was labor 120 years ago, so automatic and easily operated are today's plastics producing machines. The opinion is expressed that more and cheaper products will be available made from hitherto wasted and useless materials and every man may have luxuries and conveniences available only to comparatively few in the past when earlier materials were laboriously converted into luxury products.

Far fetched as this may appear, one is reminded of the DuPont slogan: "Better things for better living through chemistry", and plastics will do its share to accomplish the realization of this watchword. The fact remains that chemical combination never reaches an end; new possibilities stretch constantly ahead and provide uses for both old and new formulae, sometimes combinations of the two.

The new products relieve the strain on mineral resources by allowing substitution and the development of new commodities which otherwise would have had to be met by the older materials. They also require exploitation of a different group of raw materials and incur a responsibility to guard against waste of these raw materials.

The plastic industry as a whole is flexible with reference to plant location. Factories can be founded near raw materials, transportation

facilities, or labor supply, owing to the synthetic nature of the plastics material. Nearness to markets is of lesser importance because of the diversification of customers and fields of application for materials. Climate is of slight importance, thanks to the inherent qualities of plastics and the manufactured weather of air conditioning.

Specific uses for plastics have been indicated throughout this thesis, but in considering future possibilities even for present commodities we are reminded of the large numbers of people who even today have not seen or used items or services which are commonplace to the majority. When the economic capacity or social status of these people is sufficiently improved thousands of individual outlets will be created for such simple plastics as tooth brushes, cosmetic holders, or colored or transparent containers for ordinary household goods. This may affect marketing and advertising methods.

One feature of plastics is their adaptability to curved and streamlined design. For many component parts of larger equipment, or for individual consumer products, plastics afford the medium for practical expression of the designer's "New Period" ideas. Materials which change state and flow under pressure are better adapted to curved formations than to angular types.

In considering the future possibilities for expanded use of today's plastics and allowing nothing for the probable new developments, it is well to summarize their properties to find how near the field approaches the perfect plastic, and to note their limitations as compared with former standard materials. To a greater or less degree plastics are incorrodible, equally strong throughout, electrically

advantageous, heat insulating, a strengthening ingredient for wood compositions, durable, capable of being painted or plated, adapted to mass production.

Glass and porcelain are incorrodible and may be colored, but they are brittle and twice as heavy as most plastics. Mild steel, although six times as strong, is also six times as heavy, corrodible and harder to produce. Marble and stone are expensive in price and processing costs. Wood is grained, ununiform in structure, may contain internal defects, and must be selected for decorative effects, thus involving high cost, waste and expense. Most of these products have little electrical significance. To include other metals useful in electrical work would only require, in addition, the notation of inferior strength and higher cost as compared with steel.

This brief comparison together with previous references emphasizes the adaptability of plastics for miscellaneous medium strength purposes when given full opportunity. On the other hand plastics have present limitations. They are only heat resistant, and in general not fireproof; useful only for medium temperatures, not even the temperatures of equatorial countries. Their surface hardness as compared with jewels and carbon steels is inferior. Plain plastics have comparatively low compression and transverse breaking strength per square inch. Costs are high, being as much as ten times that of steel on a weight comparison basis, and prices are unstable. The price disparity will, however, be reduced as demand for plastics tonnage increases. Certain plastics tend to change shape and lose dimensional stability and color features with age. Their expansion properties are excessive for certain uses. Above

all, plastics are more subject to chemical reactions from associated materials after completion of the product than are some of the basic elements just mentioned. For this reason the plastics product must be designed for a specific purpose, thus determining to some extent which material must be used, and it must be treated properly and used intelligently by the consumer who may, through ignorance of chemical effects, ruin his new plastics purchase and blame the industry.

The more or less minor position of plastics today is noted in searching through appropriate current literature for examples of their use. Whereas outstanding features and materials pertaining to recently constructed buildings are commonly described, little attention is given as yet to specific plastics applications.

But there are frequent references by prominent designers and architects to the future of plastics as if these materials were merely awaiting distribution. Edward Wormley envisages plastics molded plywood bath tubs with transparent vinyl resin coating, plywood outdoor and indoor furniture, rattans superseded by extrusions, and cork, linoleum and wallpaper superseded by vinyl-resin coatings. (1) The practical value of plywoods in such future uses where water is concerned lies in the resin bond with the vinyls. The furniture designer's and decorator's interest in the new wood lies in the possibility of forming curved elements and fabricating original furniture and architectural trim which will stand as an independent craft entity rather than a machine-made imitation of some earlier style of design.

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(1) Wormley, Edward, Styling Furniture (Now & Then), Interiors, Vol. 101, No. 12, July 1942, pp. 50-65

On the other hand Albert Kahn, the Detroit industrial building designer, warns that stainless steel and plastics are not necessarily better than the older commonly used materials merely because they are new and growing in popularity. (1) Still, we are advised by another writer that: "Careful study indicated that in practically every instance in the building industry where any material has become difficult to obtain or has gotten out of line in price, substitutes were found which quickly met the need. Frequently such products establish a place in the market that is never fully regained by those displaced." (2) Thus the door for plastics is opened wider by the new war opportunity which imposes both materials shortages and price differentials on the total materials field and allows the use of new materials which can prove their mechanical value at an economical price.

As a final indication of what may be expected in the future it is interesting to note the following life cycle of the future "Plastic Man", as condensed from a description by Yarsley and Couzens. "This creature of our imagination, this 'Plastic Man', will come into a world of color and bright shining surfaces where childish hands find nothing to break, no sharp edges or corners to cut or graze, no crevices to harbor dirt or germs. The walls of his nursery, all the articles of his toilet, his bath, all his toys, his cot, perambulator, teething ring, the bottle he feeds from, the trays, the spoons, all will be plastic, brightly self-colored and patterned with every design likely to please his childish mind. As he grows up he cleans his teeth and brushes his

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(1) What's Happening and What's Ahead in Industrial Plant Development, Factory Management, Vol. 99, No. 4, April 1941, pp. B-37-39
(2) Prospects for 1941, American Builder, Vol. 63, No. 1, Jan. 1941, p. 33

hair with plastic brushes with plastic bristles, clothes himself in plastic clothes of synthetic silk and wool, plastic zip-fasteners, shoes, writes his lessons with a plastic pen, has books bound in plastic. He sits in a schoolroom with shining walls at a moulded desk without angles or projections.

"The windows of this school, curtained with plastic-faced cloth, are unbreakable and transmit ultra-violet rays, and the frames are of moulded plastic. The plastic floors are silent and dustless. Remember that everywhere there is a riot of color, and every kind of surface from dull matt to a mirror finish.

"The very blackboard is of dark green, matt plastic. He may have the privilege of being beaten with a synthetic plastic cane.

"Back in his home the walls of his rooms, built with panels and plastic doors covered with veneers, are protected by a transparent plastic finish. The bathroom will be all plastic; no ceramic tiles to crack, or enamel bath, but all made of plastic, white or pastel, plastic taps, and even plastic pipes. Furniture is built up of moulded plastic sections, armchairs and divans are plastic, constructed of woven plastic 'reeds', in every conceivable color.

"For beauty lampshades and stands, screens, chandeliers in transparent glass-like materials, carved and engraved, illuminated by concealed lighting; bouquettes of flowers miraculously preserved in transparent plastic, bowls and vases, all accessible to the well-to-do and taught in the craft schools of the future.

"Outside the home tennis racquets, golf clubs, fishing tackle, are all of plastic; even a motor-car, almost wholly plastic in its externals. As for the aeroplane, the lightness of plastics will revolutionize

construction, making the aeroplane the motor-car of the future. In buses, trains, and ships the same phenomenon--plastics as the possibilities are better understood. Ships, air-conditioned and insulated with plastic insulation made from film, may be finished with non-inflammable, water-resisting plates mounted on the steel structure.

"In industry, in the office, the whole interior surfacing, trays, filing cabinets, loose-leaf books, telephone, desk equipment, desks, are made of this universal material, because of its durability, surface attractiveness, clean, smooth design. In the factory every kind of housing or casing, members where lightness is required, repetition parts required in great industries like spinning or weaving will be plastic. In the electrical industry, except for conductors and magnets, almost everything will be plastic.

"But now our Plastic Man is getting tired and old. He wears a plastic denture with plastic teeth and spectacles of plastic with plastic lenses, and combs his scant hairs with a plastic comb. He still takes photographs on plastic films with a camera moulded from plastic with a plastic lens; listens to the wireless through a set encased in plastic; sits in the cinema in plastic seats; or stays at home playing with plastic cards and moulded chessmen on a plastic board, until at last he sinks into his grave hygienically enclosed in a plastic coffin.

"In how much brighter and cleaner a world he has lived than that which preceded the plastics age. It is a world free from moth and rust and full of color, a world largely built up of synthetic materials made from the most universally distributed substances--coal, water, and

construction, making the aeroplane the motor-car of the future. In buses, trains, and ships the same phenomenon--plastics as the possibilities are better understood. Ships, air-conditioned and insulated with plastic insulation made from fibre, may be finished with non-inflammable, water-resisting plates mounted on the steel structure.

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"In how much brighter and cleaner a world he has lived than that which preceded the plastics age. It is a world free from moth and rust and full of color, a world largely built up of synthetic materials made from the most universally distributed substances--coal, water, and

air. When the dust and smoke of the present conflict have blown away and rebuilding has well begun, science will return with new powers and resources. Then we shall see a cleaner and more beautiful world, an environment not subject to the haphazard distribution of nations' resources but built to order--the Plastics Age." (1)

Such a prediction of social and scientific advancement, partially supported in some respects by the present status of the plastics field and offering definite indication of fulfillment, is a fitting glimpse of the future with which to close this research thesis and needs no further word except that the opportunities for trained men to take part in this advance are limitless.

(1) Yarsley, V. E. and Couzens, E. G., Plastics, Allen Lane (Harmondsworth, England) 1941, pp. 154-158

SECTION VIII

A P P E N D I X

The chart facing this page emphasizes some of the previously mentioned characteristics of plastics. Although the first eight materials are all thermoplastic, two columns are devoted to urea and phenolic thermosetting varieties commonly associated with the name "Bakelite". Partial information relating to the older and better known materials is shown in the upper right corner of the chart. In addition to technical figures the table shows by single words what performance can be expected from various plastics.

It can be seen, for example, that while nearly all of the plastics listed have excellent general molding characteristics, the Formaldehydes are not suited to injection molding, a fact which has been mentioned previously in the thesis.

The typical thermoplastic property of the first eight materials is shown by the softening point temperatures, whereas the two Formaldehydes, being thermoset, have no practical softening point. Furthermore, most of the listed thermoplastics become distorted before reaching the softening point. The Formaldehydes can be distorted by heat but cannot be softened.

The chart also indicates general effects of acids, alkalies, sunlight, and organic solvents on the representative materials and shows that they tend to be fire-resistant but not actually fireproof.

Finally, the chart shows a wide range of light transmission from transparency to opaqueness for the thermoplastics, but a considerably more limited range for the Formaldehydes other than cast phenolics.

*GENERAL PROPERTIES OF PLASTICS INJECTION MOLDED BY THE ELMER E. MILLS CORPORATION

PROPERTIES	ETHYL-CELLULOSE PLASTIC	CELLULOSE ACETATE PLASTIC	CELLULOSE ACETATE BUTYRATE PLASTIC	VINYL CHLORIDE-ACETATE PLASTIC		VINYL CHLORIDE PLASTIC (Plasticized)	VINYLIDENE CHLORIDE PLASTIC	ACRYLATE and METHYL METHACRYLATE PLASTIC	STYRENE PLASTIC
				No Filler	Filled				
Molding Qualities	Excellent	Excellent	Excellent	Good	Excellent	Fair	Excellent	Excellent	Good
Compression Molding Temp., ° F.	320-360	250-350	270-330	240-275	250-300	220-350	220-350	300-370	220-275
Compression Molding Pressure, lbs. per sq. inch	1500-2500	1500-5000	1500-5000	1500-2000	2000-2500	500-1000	500-5000	1000-3000	1000-5000
Injection Molding Temp., ° F.	380-425	300-440	310-390	300-325	300-325	300-325	300-400	390-500	300-450
Injection Molding Pressure, lbs. per sq. inch	3000-30000	8000-30000	8000-30000	3000-30000	3000-30000	3000-30000	10000-30000	10000-30000	3000-30000
Compression Ratio	2.2-2.5	2-2.8	2.0-2.3	2.0	1.5-3.5	—	2	1.6-2.0	2.0
Mold Shrinkage, inches per inch	0.004-0.007	0.002-0.003	0.002-0.003	0.001	0.000	0.016	.004-.008	0.004-0.006	0.002-0.008
Specific Gravity	1.14	1.27-1.37	1.20-1.22	1.34-1.36	1.35-2.5	1.2-1.6	1.68-1.75	1.18-1.19	1.05-1.07
Specific Volume, cubic inch per lb.	24.3	21.8-20.2	22.8-23.1	20.7-20.4	20.5-11.1	23.0-17.3	15.8-16.8	23.4-23.2	26.3-25.8
Refractive Index, N_D	1.470	1.47-1.50	1.47-1.48	1.53	—	—	1.60-1.63	1.49	1.59-1.60
Tensile Strength, lbs. per sq. inch	6000-9000	3500-10000	3700-6800	8000-10000	6000-12000	1000-9000	5000-7000 Extruded Cordage: 20000-50000	4000-6000	6500-7000
Elongation, %	10-40	8-30	15-36	—	—	2-500	10-40	1-5	1.0
Modulus of Elasticity, lbs. per sq. inch $\times 10^5$	2-4	1-4	—	3.5-4.1	3.5-8.5	—	0.8-1.7	—	3.75-4.25
Compressive Strength, lbs. per sq. inch	10000-12000	11000-27000	11300-20300	—	—	—	—	10000-15000	13000-13500
Flexural Strength, lbs. per sq. inch	9000-10000	5000-16000	5600-11900	10000-13000	7500-12000	—	15000-17000	10000-15000	14000-19000
Impact Strength, ft. lbs. energy to break ½ × ½ inch bar C = Charpy, I = Izod	0.6-1.8 I	0.9-1.6 C	1.3-3.3 C	0.3-0.6 I	0.1-0.7 I	—	2-8 I	0.2-0.4 C	0.4-0.6 I
Hardness (2.5 mm. ball, 2.5 kg. load), Brinell No.	—	8-15 (10 kg.)	9-11 (10 kg.)	15-25	15-25	—	—	18-20	20-30
Thermal Conductivity, 10^{-4} cal. per sec. per. sq. cm./1° C. per cm.	5.6	5.4-8.7	7.7	4.0	Varies	3.9-4.0	2.2	—	1.9
Specific Heat, cal. per ° C. per gram	0.25-0.40	0.3-0.45	0.35	0.24	Varies	0.32-0.51	.316	0.4-0.5	0.32
Thermal Expansion, 10^{-5} per ° C.	10-14	14-16	13-15	6.9	Varies	—	15.8	8-9	7-8
Resistance to Heat, ° F. (continuous)	140-180	140-180	140-200	—	—	150	240-280	120-140	—
Softening Point, ° F.	210-265	145-260	140-250	130-160	130-160	—	240-280	150-230	190-250
Distortion under Heat, ° F.	130-150	122-212	136-200	140-150	140-158	—	140-170	125-160	150-190
Tendency to Cold Flow	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight	Slight
Volume Resistivity, ohm.-cms. (50% relative humidity and 25° C.)	10^{15}	$(1\text{-}6) \times 10^{12}$	—	$> 10^{14}$	10^{11}	8×10^{13}	10^{14} - 10^{16}	10^{15}	10^{17}-10^{18}
Breakdown Voltage, 60 cycles, volts per mil (instantaneous)	1500	350-900	—	650	—	600-2000	500-2500	500	500-700
Dielectric Constant, 60 cycles	—	4.5-6.2	3.6	—	—	12.0	3-5	3.0-3.1	2.6
Dielectric Constant, 10^3 cycles	2.5-3.5	4.5-6.0	—	—	4.7	—	3-5	3.3-3.5	2.6
Dielectric Constant, 10^6 cycles	2.0-3.0	4.0-5.0	3.6	4	4	—	3-5	3.1-3.3	2.6
Power Factor, 60 cycles	—	0.01-0.04	0.014	—	—	13.6	0.03-0.08	0.05-0.06	0.0003
Power Factor, 10^3 cycles	0.005-0.025	0.02-0.06	—	0.014	0.02-0.15	—	0.03-0.15	0.06-0.07	<0.0003
Power Factor, 10^6 cycles	0.007-0.03	0.04-0.06	0.018	0.018	0.02-0.065	—	0.03-0.05	0.02-0.03	<0.0003
Water Absorption, immersion—24 hrs.	1.25 (48 hrs.)	1.4-2.8	0.8-1.1	0.05-0.15	0.2-4.0	—	0.00	0.4-0.5	0.00
Burning Rate	Slow	Slow	Slow	Nil	Nil	Nil	None	Slow	Slow
Effect of Age	Slight	Slight	Slight	Strength unaffected	None	None	None	Practically Nil	Very slight
Effect of Sunlight	Slight	Slight	Slight	Darkens	Discolors	None	Slight	Very slight	Yellows slightly
Effect of Weak Acids	Slight	Slight	Slight	Resistant	Dependent on filler	None	None	Practically Nil	None
Effect of Strong Acids	Decomposes	Decomposes	Decomposes	Resistant	Dependent on filler	None	Highly Resistant	Affected only by oxidizing acids	None
Effect of Weak Alkalies	None	Slight	Slight	Resistant	Dependent on filler	None	None	Practically Nil	None
Effect of Strong Alkalies	None	Decomposes	Decomposes	Resistant	Dependent on filler	None	Highly Resistant	Practically Nil	None
Effect of Organic Solvents	Widely soluble	Soluble in ketones and esters; softened or slightly soluble in alcohol; little affected by hydrocarbons		Resists alcohols, aliphatic hydrocarbons, and oils. Soluble in ketones and esters; swells in aromatic hydrocarbons		Soluble in ketones and esters	Highly Resistant	Soluble in ketones, esters and aromatic hydrocarbons	Soluble in aromatic and chlorinated hydrocarbons
Effect on Metal Inserts	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert	Inert
Machining Qualities	Good	Good	Good	Good	Good	Good	Good	Excellent	Poor to good
Clarity	Transparent translucent opaque	Transparent translucent opaque	Transparent translucent opaque	Transparent translucent opaque		Transparent to opaque	Translucent To Opaque	Transparent (90-92% light transmission) Also translucent and opaque	Transparent (90-92% light transmission) Also translucent and opaque
Color Possibilities	Unlimited	Unlimited	Unlimited	Unlimited, pastels to black		Unlimited	Unlimited, Translucent and Opaque	Unlimited	Unlimited

*The tables above are reprinted by courtesy of Modern Plastics magazine

PROPERTIES OF OTHER MATERIALS LISTED FOR COMPARISON WITH PROPERTIES OF INJECTION MOLDED PLASTICS

NOTE: The relative position occupied by injection molded plastics is apparent by the comparison of plastic properties with those of the materials shown below. The values given are not all-inclusive, but represent the ordinary values obtained with these materials. The values are solely comparative.

PROPERTIES	UREA-FORMALDEHYDE COMPOUND	PHENOL-FORMALDEHYDE COMPOUNDS		Hard Rubber	Cast Gray Iron	Cast Brass	Zinc Die Castings	Aluminum Die Castings	Common Glass	Ordinary Wood
		Molding	Cast							
	Alpha Cellulose Filler	Woodflour Filler	No Filler							
Molding Qualities	Excellent	Excellent	—							
Compression Molding Temp., ° F.	290-325	280-360	—							
Compression Molding Pressure, lbs. per sq. inch	1500-6000	2000-4500	—							
Injection Molding Temp., ° F.	3	—	—							
Injection Molding Pressure, lbs. per sq. inch	—	—	—							
Compression Ratio	3	2.2-3.0	—							
Mold Shrinkage, inches per inch	0.006-0.011	0.006-0.010	—							
Specific Gravity	1.45-1.50	1.25-1.52	1.27-1.32	1.12-1.80	7.1	8.4	6.6	2.9	2.6	.40-.85
Specific Volume, cubic inch per lb.	19.1-18.5	22.2-18.2	21.8-20.0	24.7-15.4	3.8	3.3	4.2	10.0	10.7	72.8-32.0
Refractive Index, N_D	1.54-1.6	—	1.5-1.7						1.4-1.5	
Tensile Strength, lbs. per sq. inch	9000-12000	4000-11000	5000-12000	4000-10000	20000-30000	30000-35000	36000-48000	29000-33000	200000-300000	—
Elongation, %	—	—	—	2-15	0-2.0	2.5-3.5	2.0-5.0	1.0-3.0	—	—
Modulus of Elasticity, lbs. per sq. inch $\times 10^5$	12-15	10-15	5-15							
Compressive Strength, lbs. per sq. inch	24000-35000	16000-36000	15000-30000	8000-12000	65000-100000	85000-90000	60000-90000	60000-70000	—	—
Flexural Strength, lbs. per sq. inch	10000-13000	8000-15000	—							
Impact Strength, ft. lbs. energy to break ½ × ½ inch bar C = Charpy, I = Izod	0.14-0.16 I	0.10-0.28 I	0.1-1.5 I	—	.25-2.0	10-30	15-35	1.0-5.0	0	—
Hardness (2.5 mm. ball, 2.5 kg. load), Brinell No.	48-54 (500 kg., 10 mm.)	30-45	30-45	31***	130-210*	40-50**	70-85**	70-85**	—	—
Thermal Conductivity, 10^{-4} cal. per sec. per. sq. cm./1° C. per cm.	7.1	4-12	3-5	3.2	.11‡	.34‡	.26‡	.27‡	.002‡	.0001-‡ .0003
Specific Heat, cal. per ° C. per gram	—	0.35-0.36	0.3-0.4		.11	.09	.10	.22	.16	.42
Thermal Expansion, 10^{-5} per ° C.	2.5-3.0	3.7-7.5	2.8		1.1	1.9	2.6	2.5	.8	
Resistance to Heat, ° F. (continuous)	160	350	160							
Softening Point, ° F.	None	None	—							
Distortion under Heat, ° F.	260	240-285	—							
Tendency to Cold Flow	None	None	—							
Volume Resistivity, ohm.-cms. (50% relative humidity and 25° C.)	$(2\text{-}2.8) \times 10^{13}$	10^{10}-10^{12}	10^{9}-10^{14}							
Breakdown Voltage, 60 cycles, volts per mil (instantaneous)	650-720	300-500	300-450							
Dielectric Constant, 60 cycles	7-8	5-12	5-10							
Dielectric Constant, 10^3 cycles	—	4-8	—							
Dielectric Constant, 10^6 cycles	6	4.5-8	5-7							
Power Factor, 60 cycles	0.040-0.048	0.04-0.30	0.025-0.20							
Power Factor, 10^3 cycles	—	0.04-0.15	0.005-0.08							
Power Factor, 10^6 cycles	0.01-0.03	0.035-0.1	0.01-0.045							
Water Absorption, immersion—24 hrs.	1-2	0.2-0.6	0.01-0.5							
Burning Rate	Very low	Very low	Very low							
Effect of Age	Hardens slightly	None	Hardens slightly							
Effect of Sunlight	None	Light shades discolor	Colors may fade							
Effect of Weak Acids	——	None to slight depending on acid								
Effect of Strong Acids	Decomposed or surface attacked	Decomposed by oxidizing acids; reducing and organic acids no effect								
Effect of Weak Alkalies	——	Slight to marked depending on alkalinity								
Effect of Strong Alkalies	Decomposes	Decomposes	Decomposes							
Effect of Organic Solvents	——	None on bleed-proof materials	None							
Effect on Metal Inserts	Inert	Inert	Inert							
Machining Qualities	Fair	—	Excellent							
Clarity	Translucent opaque	Opaque	Transparent translucent opaque							
Color Possibilities	Unlimited; pastel shades	Limited	Unlimited							

*—10 mm. ball, 500 kg. load. **—10 mm. ball, 3000 kg. load. ***—2.5 mm. ball, 25 kg. load. ‡—X1.

The scope of injection molding is being constantly expanded by the development of new materials and by improvements in present molding materials.

We are instantly advised of these increased advantages, as soon as they are available. Accordingly, we suggest that you secure this information from us before you determine the molding material for the casting of your plastic products.

Our engineers will be glad to give you the most recent developments in molding materials without cost or obligation to you. In this manner you are assured all the benefits that plastics offer.

We specialize in custom injection molding to the exclusion of other processes of plastic fabrication.

We are glad to offer our services to you and to make recommendations of materials and the preferable method of manufacture of products which cannot be molded by the injection process.

NOTE: The tables on the left show the range of physical properties of plastics for injection molding. Such figures necessarily show a wide spread, and it should be understood that no one formula could have all the qualities of the limits shown. For instance, it would be impossible to supply a molded article from these materials having both very high elongation and very high flexural strength, as one is somewhat opposite the other. Such is true of any material whether natural or synthetic.

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DATE	ISSUED TO
4 40	Miss Cosgrove
4 -	David Brown
2.30	Arlene McAnenia
2:20	A. Coffey
2:50	Eugene Geyer